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An Integrated Methodology to Study Site Formation Processes on Submerged Shipwrecks in the 21st c.

By
Rodrigo Ortiz Vázquez

Thesis for the degree of Doctor in Archaeology

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Abstract

Submerged shipwreck sites are dynamic open systems that require a multiple-approach method to capture their complexity adequately. Conventional methods of recording and monitoring these sites have resulted in mono-dimensional models by focusing primarily on macro- or micro-scale studies. Fortunately, the application of new technologies to record underwater cultural heritage (UCH) has pushed the boundaries of maritime archaeology. Recent advances in remote sensing techniques provide valuable tools for collecting data rapidly with a high degree of accuracy and detail. However, while compelling digital outputs can be generated (Demesticha, Skarlatos, and Neophytou 2014; Drap, Merad, et al. 2015; Nayling and Jones 2014; PAS 2017; Pieraccini, Guidi, and Atzeni 2001; Plets et al. 2009; Yamafune 2016), we have to consider their analytical potential/ability to contribute by exploring their capabilities and limitations.

With the above in mind, this thesis addresses the lacuna in the analysis of site formation processes (SFP) on shipwrecks, by presenting an analytical understanding of data collection and presenting an integrated methodology. Demonstrating a flexible approach adapting to a variety of environments on *Hazardous 1706, Rooswijk 1740, and Invincible 1758.* Bracklesham Bay (*Hazardous*), the Goodwin Sands (*Rooswijk*), and The Eastern Solent (*Invincible*), offers a broad spectrum of highly dynamic environments in shallow water. Rarely do archaeologists get the opportunity to carry out extensive pre-disturbance surveys and excavations, and collect first-hand data periodically, on the same wrecks. Over the years 2016-2018 a number of international projects on *Invincible* (2013-2018) *Rooswijk* (2017-2018) and *Hazardous* (2016-2018) made it possible to develop and carry out this research. This opportunity was highly significant in bridging the gap between management policies, and targeted research of site formation processes enhancing our shipwreck interpretation of these historically significant vessels.

Shipwrecks are complex systems composed of material culture regulated by anthropogenic and taphonomic processes. Geo-acoustic methods offer accurate tools (<.2m) for macro-scale taphonomy (e.g. *Stirling Castle 1703* (Astley 2016; Bates et al. 2011), or *Fougeoux 1805* (Fernández-Montblanc et al. 2016)). However, they overlook the pressing need to attend to the intra-site level analysis concerning the shipwrecks' integral coherence, combined with diver based *in situ* observations. The high-resolution time-series, acquired by computational optical imaging and acoustic positioning, presented in this thesis, provides that intra-site or micro-level analysis.

It is critical to use a multi-scalar approach of time and space, as understanding changes on a shipwreck require moving between *synchronic* and *diachronic* analysis. This is possible by integrating previous work on site, as well as presenting the extant shipwrecks' structure and artefact distribution. The use of new technologies allows capturing three-dimensional (3D) structures throughout time (4D), instead of traditional insufficient two-dimensional (2D) recording methods. This opens a new realm of possibilities for capturing quantitative and qualitative data, offering innovative display methods with analytical tools. Efficiency is paramount to record and analyse UCH, considering that *in situ* preservation is impossible, due its entropic nature: it is a finite resource bound to disintegrate.

Keywords:
Underwater cultural heritage, shipwrecks, site formation processes, maritime archaeology, integrated methodology, remote sensing

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Abbreviations

AIA. Archaeological Impact Assessment
ABP. Associated British Ports
ACOP. Approved Code of Practise
ADM. Admiralty
ADS. Archaeological Data Service
ADU. Archaeological Diving Unit
ALB. Airbourne Laser Bathymetry
BBC. British Broadcast Channel
BGS. British Geological Survey
Black Sea MAP. Black Sea Maritime Archaeology Project
CD. Chart Datum
CMA. Centre for Maritime Archaeology
CCO. Channel Coast Observatory
CONACYT. National Council of Science and Technology
(Consejo Nacional de Ciencia y Tecnología, Mexico)
CA. Cotswold Archaeology
D-GPS. Differential Global Positioning System
DWR. Diving at Work Regulation
EDINA. University of Edinburgh Digital Archive
EH. English Heritage
EIA. Environmental Impact Assessment
GSHHS. Global Self-consistent Hierarchical High-resolution Shorelines
GEBCO. General Bathymetric Chart of the Oceans
GNSS. Global Navigation Satellite System
GPS Global Positioning System
HER. Historic Environmental Record
HO. Hydrographic Office
HM. Her Majesties
HMS. His/her Majesties Ship
HWTMA. Hampshire and Wight Trust for Maritime Archaeology
HSE. Health and Safety Executive
IJNA. International Journal of Nautical Archaeology
IMCA. International Marine Contractors Association
IMU. Inertial Measurement Unit
LBL. Long Baseline
LIDAR. Light Detection and Ranging
JMA. Journal of Maritime Archaeology
NA. National Archive
NAS. Nautical Archaeology Society
NHA. National Heritage Act
NMR. National Monuments Record
NMM. National Maritime Museum.
NERC. Natural Environmental and Research Council
NFSD. National Facility for Scientific Diving
NOC. National Oceanography Centre
MAT. Maritime Archaeology Trust (*formally HWTMA*)
MBES. Multibeam Echo-Sounder

MCA. Maritime and Coastguard Agency
MSDS Marine. Marine and Coastal Archaeology Contractor
MV. Motor Vessel
OD. Ordinance Datum
ODN. Ordinance Datum Newlyn
PAS. Pascoe Archaeological Services
PWA. Protected Wrecks Act (1973)
RCE. Cultural Heritage Agency of the Netherlands. Ministry of Education, Culture and Science.
RN. Royal Navy
RV. Research Vessel
RTK. Real-Time Kinematics
SBP. Sub-bottom Profiler
SCC. Southampton City Council
SCOPAC. Standing Conference on Problems Associated with the Coastline
SSS. Side Scan Sonar
TCE. The Crown Estate
T-GIS temporal geographical information system
UCL. University College of London
UCH. Underwater Cultural Heritage
UK. United Kingdom
UKHO. United Kingdom Hydrographic Office (*formally HO*)
UNESCO. United Nations Educational Scientific and Cultural Organisation
UoS. University of Southampton
USBL. Ultra-Short Baseline
USV. Unmanned Surface Vessels
VOC. Dutch East Indiamen (*Vereenigde Oost-Indische Compagnie*)
VORF. Vertical Offshore Reference Frame
WA. Wessex Archaeology
WR. Wreck Record

Academic Thesis: Declaration Of Authorship

I, Rodrigo Ortiz Vázquez declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

Shipwrecks as part of the Modern World Maritime Landscape. An Integrated Methodology to Study Site Formation Processes on Submerged Shipwrecks in the 21st c

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission

Signed: ....

Date: ....

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Chapter I

1.1 Introduction

This thesis presents a comprehensive approach to maritime archaeological research with a particular focus on site formation processes of submerged shipwrecks. It ventures to combine theory, methods and a variety of practices to "*study remains of past human activities on the seas*" (Adams 2013a:2).

Thirty years ago, Muckelroy argued that ships and boats are one of the most highly complex artefacts produced by human society:
"In any pre-industrial society, from the upper Palaeolithic to the nineteenth century A.D., a boat or (later) a ship was the largest and most complex machine produced" (Muckelroy 1978a:3).

Certainly, boats or ships were probably the most complex machine produced, until the age of deep sea and space exploration. However, ships and later shipwrecks acquire another dimension of importance when placed into context (historically, archaeologically and environmentally) and we understand them as an element of the maritime landscape. Shipwrecks represent a material record (in all their varieties: ships, rafts, dugouts, hide floats, basket boats, pot boats, canoes, (McGrail 2001:7–11) [carriers, submarines or other watercraft]) of human behaviour and the interaction with their surrounding landscape; thus by studying them, we increase our understanding of human history.

This thesis aims to understand submerged shipwrecks within their maritime landscape, as well as the natural (*n-factors*) and cultural (*c-factors*) (Schiffer 1987:7) processes they endure. The combination of adequate recording methods will bridge the gap between macro- and micro-scale[1] studies of this finite Underwater Cultural Heritage (UCH) asset. A crucial point for fully understanding shipwrecks is that whether it is a submerged, intertidal, or land site, none should be seen as a "*time capsule*". Nor should they be considered as "*simply sealed by time*" (Adams 2013a:21;

[1] Also known as intra-site interpretation (Adams and Rönnby 2013a; Eriksson 2013).

Dean et al. 1992:32; Gould 2000:12; Muckelroy 1976a:56–57; Tovar-Herrera 2008:113). The following paragraphs examine why this is the case.

The characterisation of a dynamic environment to classify a shipwreck site, showing its changing nature, is far from simple. However, this dissertation aims to present shipwrecks as a dynamic entity containing an elaborate material record of human behaviour and interaction with their environments. This is the opposite of a portrait, map or a photograph that is "frozen" in time. Inevitably, ships as any other object, are subject to change as time passes, from the moment selected timbers are used for their building process (Tovar-Herrera 2008:113), to the moment they cease to be in use becoming part of the archaeological record. Even then, as archaeological sites or objects in a museum display, they are continuously changing. Hence, comparing a shipwreck with a 'time capsule' only understates its dynamic nature. The study of these archaeological objects (shipwrecks), composed of several artefacts studied from a *synchronic* [2] and a *diachronic* [3] evaluation, provides a different breadth of study. However, it is important to clarify that there are two types of *diachronic* analysis. The first is a site-level modelling approach that integrates environmental conditions and its impact on the shipwreck site, like the ones presented in this thesis; with 4-dimensional (4D) modelling, consisting 3-dimensional (3D) spatial representation with an added dimension of time, that allows for the representation of changes in the archaeological record. This is extremely useful for site assessment in order to evaluate site vulnerability and better cultural heritage care strategies.

The second is a more a historical-diachronic analysis that focuses on technological innovation and the associated social changes. This requires a great effort of syntheses, tracing the technological change in shipbuilding techniques, motivated by resource availability, tradition, purpose, political and socio-economic processes (Adams 2013a:23). Nautical archaeology [4] offers the possibility of understanding these shipbuilding techniques on a wide variety of watercraft, placed within their historical context (Muckelroy 1978a:9). There are exemplary studies of boatbuilding traditions and their changes through the archaeological record in different boat building traditions (Adams 2013a; van Duivenvoorde 2015; Englert 2015; McGrail 2001; Rieth 2016; Steffy 1994). However, this type of research goes beyond the scope of this thesis.

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[2] At one point in time.

[3] Throughout time.

[4] Nautical archaeology understood as an area of study of maritime technology, with a particular concern for boat building (Muckelroy 1978a:9).

Instead, the focus here is to better understand the site formation processes on submerged wreck sites. By modelling the dynamic nature of wrecks it is possible to reverse engineer what these wrecks were like as a ship in their systemic context (Schiffer 1987). An integrated methodology is proposed here as well as further critical analysis of the cultural heritage documentation and data quality used to interpret the wrecking process. The integrated methodology has been produced to ensure flexibility to adapt to any wreck site.

1.2 Justification and Motivation

Shipwrecks are unique and complex assemblages that combine the structural remains of the ship (coherent or scattered) with an extensive variety of objects, such as cargo, personal belongings, and on occasion intrusive material (Adams 2013a; Adams and Rönnby 2013a; Martin 2014; Muckelroy 1978a:3). A ship's archaeological remains reveal more about culture when they illuminate broader questions of social organisations, resource use and even human reasoning (Hocker 2013). They can present a detailed insight into the nature of daily life, warfare, politics, and associated symbolism that are a part of ongoing social changes and technical problem-solving (Rönnby 2013). These qualities make shipwrecks an essential class of source material with high potential for historical and archaeological interpretation such as the approach presented in this thesis.

The majority of on-going monitoring work of submerged wrecks have focused on the comparison of geophysical/remotely sensed data, and less so on intra-site observation (Astley 2016; Ford et al. 2016; Keith and Evans 2016; Quinn 2006; Quinn et al. 1998, 2007; Quinn and Boland 2010; Quinn and Smyth 2017). On the other hand, some archaeological research interested in intra-site scale studies has focused on the spatial distribution of wrecks and their artefacts, whilst overlooking environmental dynamics on a macro or mesoscale (Bernier 2007; Elkin 2007; Holland 2015; Martin 2017; O'Shea 2002). This thesis aims to bridge the gap between macro, meso and intra-site scale studies by integrating all approaches.

There have been previous efforts to explain the wrecking processes and site formation processes including both environmental and cultural dynamics (Gibbs 2006; Muckelroy 1978a; Oxley et al. 2016; Stewart 1999; Ward, Larcombe, and Veth 1999). However, the combination of theoretical approaches with case studies demonstrating both macro and intra-site scale is less frequent. This thesis contributes to the theoretical approach of site formation processes and demonstrates how this theory is put into practice with case study examples.

The use of remote sensing techniques and marine geophysics, in particular, are widely used to understand seabed morphology and the dynamic processes of seafloor volcanism, tectonics, mass wasting and sediment transport (Becker et al. 2009; EMODnet 2016, 2018; Ryan et al. 2009). These non-intrusive techniques are powerful tools to provide a macro-scale perspective on site formation processes of underwater sites, by integrating environmental data with marine geophysics. Depending on their resolution, the maps generated by these geo-acoustic methods can trace and quantify sediment budget (erosion, deposition, and mobility) and explain patterns of flow/scouring, of anthropogenic structures (Bates et al. 2011; Evans and Firth 2016; Fernández-Montblanc et al. 2016; Quinn 2006; Quinn and Smyth 2017). However, a time-lapse bathymetric record requires a site-tailored systematic methodology (multi-annual) (Astley 2016), and even then *in situ* observation is still a critical part of interpreting the geophysical data.

Other integrated approaches have been applied to study site formation processes on wrecks such as combining sub-bottom profiler (SBP) and side-scan sonar (SSS) surveys, thus allowing access to what lies beneath the seabed. This approach was successfully demonstrated on the *Mary Rose* (Quinn, Bull, Dix, et al. 1997) and the *Invincible* (Quinn et al. 1998). On the *Mary Rose,* it was possible to define the scouring on the seabed left by years of accretion and erosion caused by the wreck site (Quinn, Bull, and Dix 1997). Taking this further, on the *Invincible* an integrated approach using marine geophysics (SBP and SSS) and the archaeological record managed to create an innovative model of the wreck site (Quinn et al. 1998).

More recently, an improved 3D chirp system recorded a pseudo-3D volume on the *Yarmouth Roads wreck* (Plets, Dix, and Best 2008) and a real 3D volume of the *Grace*

Dieu (Plets et al. 2009). These studies indicate the potential to map buried hull remains and identify areas of archaeological interest. However, the resolution does not allow precise identification and recording of structural features of the shipwrecks. It is crucial to understand the shipwreck structure first, along with the spatial distribution of activities within its construction, before successfully explaining how it gradually loses coherence[5]. The only true method to obtain the intra-site resolution level is by integrating pre-disturbance (remote sensing) surveys and archaeological excavation with a high-resolution recording of the wreck.

Although marine geophysics have undoubtedly played a vital role in the site management of wrecks there are limitations to using seismic reflective techniques to identify archaeological material (Quinn et al. 2005; Quinn, Bull, Dix, et al. 1997). The surveys are usually both infrequent and are typically carried out to different standards, thus it can be unclear how well they represent what is happening *in situ*.

On the other hand, some studies have focused more on the intra-site level analysis of the site formation process effects on shipwrecks (Ferrari 1994; Holland 2015; Merret-Jones 2000; Palma 2005; Richards 2011; Tizzard et al. 2014). These have mainly focused on the threats to underwater cultural heritage and monitoring the physical, chemical or biological degradation of sites. Whilst some studies (Björdal et al. 2012; Gregory 2015; Gregory and Manders 2011; Manders, M.R. & Al-Hamdani 2011; Richards 2011; Tomalin, Simpson, and Bingeman 2000) produce valuable information for heritage management, most of them overlook the importance of integrating remote sensing data to provide a broader study scale.

It is difficult to understand or represent an object such as a shipwreck when it is subject to constant change depending on the environmental conditions. However, it is possible to create predictive modelling, based on previous conditions, to create a proxy for reality. We can draw an analogy between the "shipwreck paradox" and Schrödinger's "cat paradox" theory (Schrödinger 1980). Schrödinger theorised that if you put a cat in a box with a poison that might kill it, at the end of an hour the cat has a 50% chance of

[5] Site classification is further explained in Chapter 4, with three main categories: high, moderate and low-energy (EMODnet 2018), and with sub categories, coherent, scattered ordered, and scattered disordered (Muckelroy 1978:164).

being alive and a 50% chance of being dead. Since we cannot see in the box to know if the cat is alive or dead, the cat is both alive and dead. Of course, we know that nothing can be alive and dead at the same time. However, we cannot be entirely sure if the cat is alive or dead inside the box until we open it up[6]. That being said, if we had the possibility to x-ray the box or access to a thermal camera, we could infer the state of that animal without opening the box.

Similarly, we cannot be entirely certain of the state of the wreck until we re-visit the site and answer questions such as, what level of decay does it have? Or has it been destroyed? However, with the appropriate tools, and a consistent methodology, it is possible to infer the state of the wreck (See Chapter III). This problem also raises another question of the importance of data resolution to capture and explain the changes on a wreck site. The higher the data resolution we have to model the wreck, the better the possibilities we have to understand the real state of a site.

This thesis recognises the challenge of representing what a wreck looks like underwater and endeavours to address it by combining different resolution surveys. If we can only quantify or capture resolution to X level, how can we describe or interpret to Y level? To be clear, this does not mean that we generate better modelling simply by collecting more data. Instead, it is meant that the quality of the data has a direct impact on our capacity to model an archaeological site.

The primary motivation for this thesis was the possibility to carry out extensive pre-disturbance surveys, excavations and collect first-hand data periodically, on the three wrecks: the *Hazardous*, *Rooswijk* and *Invincible*. This represented a unique opportunity, with these three different wrecks being excavated during 2017 and 2018, to create and test the effectiveness of the methodology presented in this thesis. This research, therefore, contributes to better-informed interpretations of site formation processes of the presented shipwrecks, as well as offering a comprehensive methodology to study other sites in the UK and around the world.

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[6] Schrödinger only proposed this as a thought experiment. He did not actually test it on a real cat. He was trying to make a point saying that the cat cannot be dead and alive at the same time.

Shipwrecks have been a central concern in underwater and maritime archaeology since the birth of the discipline as a scientific study, with the study of the *Cape Gelidonya* and the *Uluburun* wreck in 1976 (Bass 1961, 1968, 2012; Bass et al. 1989). In British waters, some of the first historical wreck-sites to be positively identified were a Dutch East Indiaman (VOC), *De Liefde* (1711), off the Outer Skerries (Shetland Isles) (Bax and Martin 1974), another *VOC* the *Amsterdam* near Hastings (Marsden 1972, 1974), followed by the Spanish Armada wrecks *Santa María de la Rosa* (Martin 1975) and the *Girona* (Stenuit 1972). However, a key date in British maritime archaeology was 1973, when the *Mary Rose* (1545) was found (Mckee 1982), and the Protection of Wrecks Act (PWA) enacted.

In the UK, the *Mary Rose* excavation and subsequent 40 years of continued studies, is an exemplary world-leading and ground-breaking project with extensive publications and an impressive museum display. The Mary Rose Museum has demonstrated the immense potential for continued research, development, education and public outreach for wrecks. However, much is still to be done in terms of monitoring the changes to the extensive structural remains by introducing a monitoring programme during the post-conservation stage, making the most of new technologies (further discussed in Chapter III). Not all shipwrecks have generated the same interest or detailed, in-depth studies. Therefore, creating new information and revisiting some wrecks that have had the previous site formation process studies, can provide radically different interpretations to previous ones made on site. If we do not understand how the site came to be as we found it, any subsequent conclusions might be seriously flawed (Adams 2013b:10).

To put things into perspective, there are over 60,000 wrecks estimated in UK territorial waters[7] (Cant 2013), of which approximately 20,000 are named vessels, and kept on record by the UKHO (NA 2018) (Figure 1). However, only 68 have been designated as protected wreck sites (England: 53, Scotland: 8, Wales: 6, and Northern Ireland: 1) under the PWA (1973)[8], and Marine Protected Areas (MPA) (Historic Environment

[7] Every State has the right to establish the breadth of its territorial sea up to a limit not exceeding 12 nautical miles (UN 1982b).
[8] As of 1 November 2013, section 1 of the Protection of Wrecks Act 1973 has been repealed in Scotland. Sites previously designated under this legislation have been

Scotland 2016) due to their exceptional historical value (Figure 2). Furthermore, only four are wreck sites in England are catalogued as at high-risk (HE 2017b)(Figure 2). The legal framework includes additional support by the Protection of Military Remains Act (PMR) that protects 91 (Designated vessels: 79, and Designated Controlled Sites: 12) designated wreckage of military aircraft and specific military wrecks administered by the Ministry of Defence (MOD)[9] (MOD 2014, 2017; The Crown Estate 1986). In England's territorial waters, there are currently six Controlled Sites of a total of 12 in the UK (Figure 3). Further to this, there are 450 Protected Places, of which 434 are recorded aircraft (HE 2017). All these wrecks represent direct archaeological evidence of maritime activities that go back up to 6,000 years and have undergone significant changes over the course of this period, reflecting changes in the societies that produced them.

designated as Historic MPAs under the Marine (Scotland) Act 2010, or de-designated altogether (Historic Environment Scotland 2016).

[9] The PMR Act applies to any aircraft, which has crashed, while in military service. Considering that, the vessel sank or was stranded on or after the 4th August 1914 (The Crown Estate 1986:1–2).

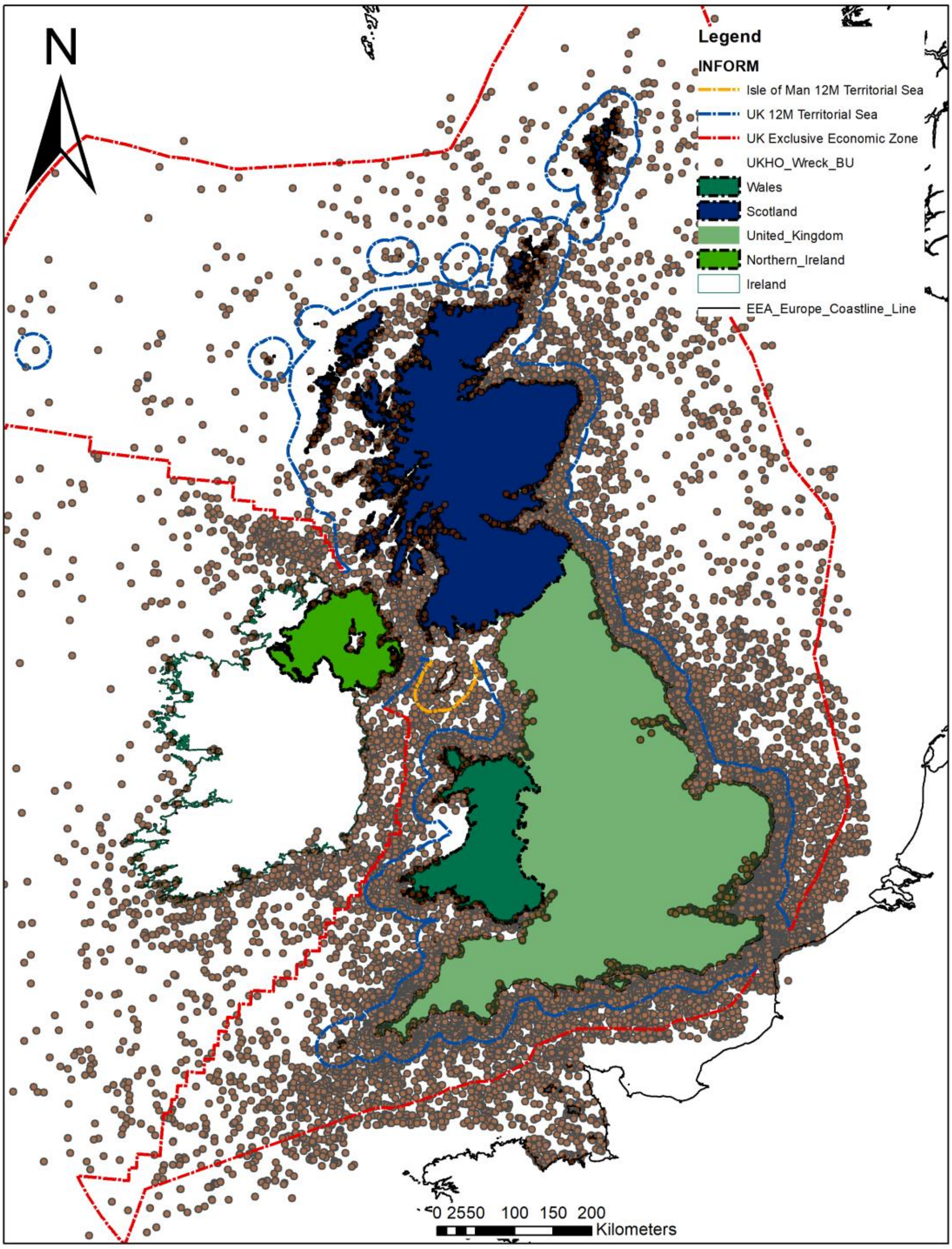

Figure 1. The map is showing an outline of the coastline, made by plotting a high-density distribution of wrecks around the UK. The map is made from Digimap® data (Edina 2018)**, courtesy of Bournemouth University. The wreck locations taken from the United Kingdom Hydrographic Office (UKHO) and are also available at EMODnet** (EMODnet 2018)**. The UK Territorial Waters are plotted by EMODnet and Continental Europe by the European Environmental Agency The protected wreck locations are based on HE Maritime Protected Wreck Sites as in 2018 (HE Maritime 2017). The author of this thesis created the map on ArcMap 10.5®.**

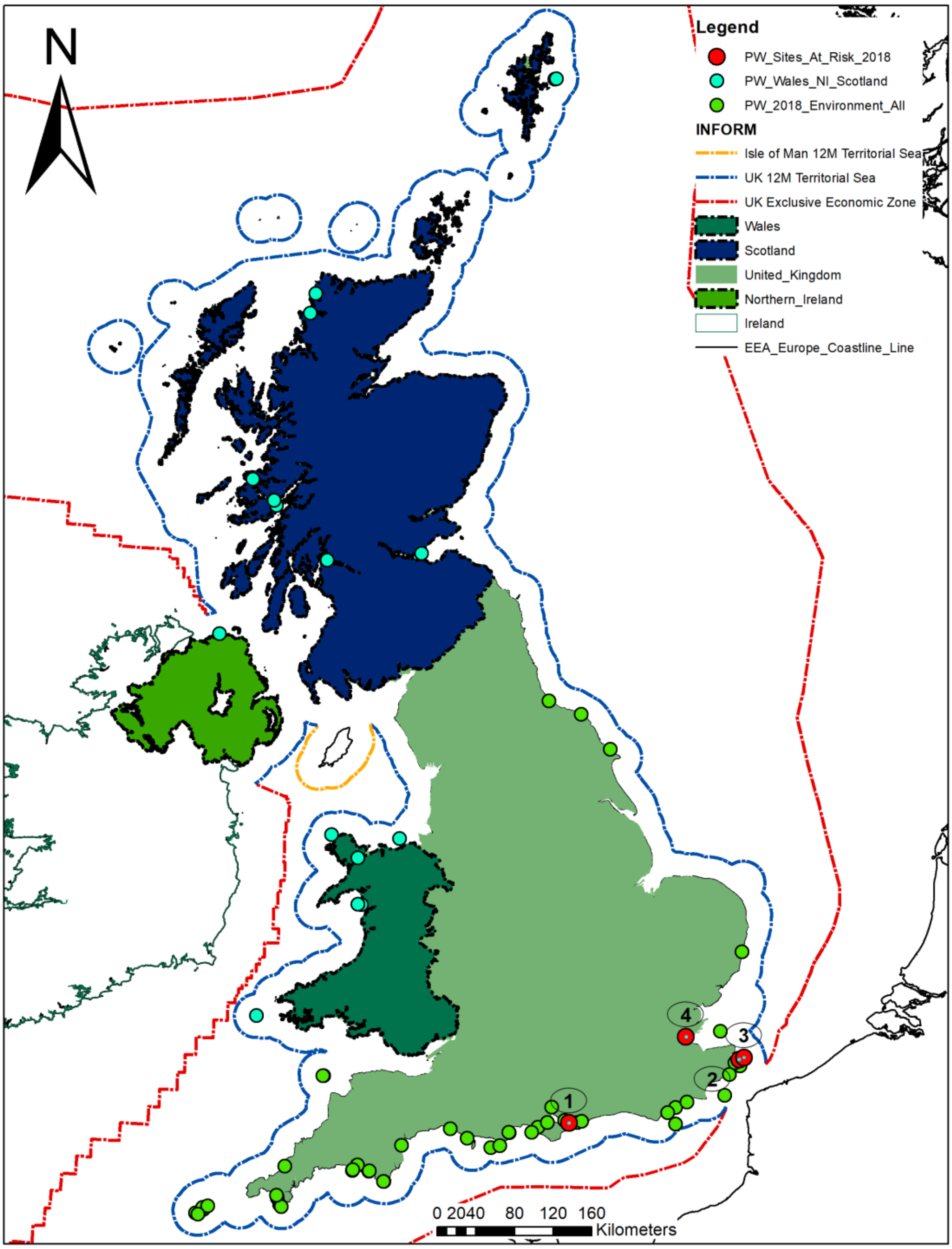

Figure 2. The map shows the distribution of protected wreck sites in the UK. Highlighting the wrecks catalogues as at risk: 1. ***Invincible (1758), 2. Northumberland (1703), 3. Rooswijk (1740), and 4. London (1665)*** (HE 2017b)**. The wreck locations are based on HE Maritime Protected wreck sites as in 2017 (HE Maritime 2017). The coastline is NGA** (National Geospatial-Intelligence Agency 2018)**, EMODnet** (EMODnet 2018) **and EEA** (EEA 2018)**. The author of this thesis created the map of ArcMap 10.5®.**

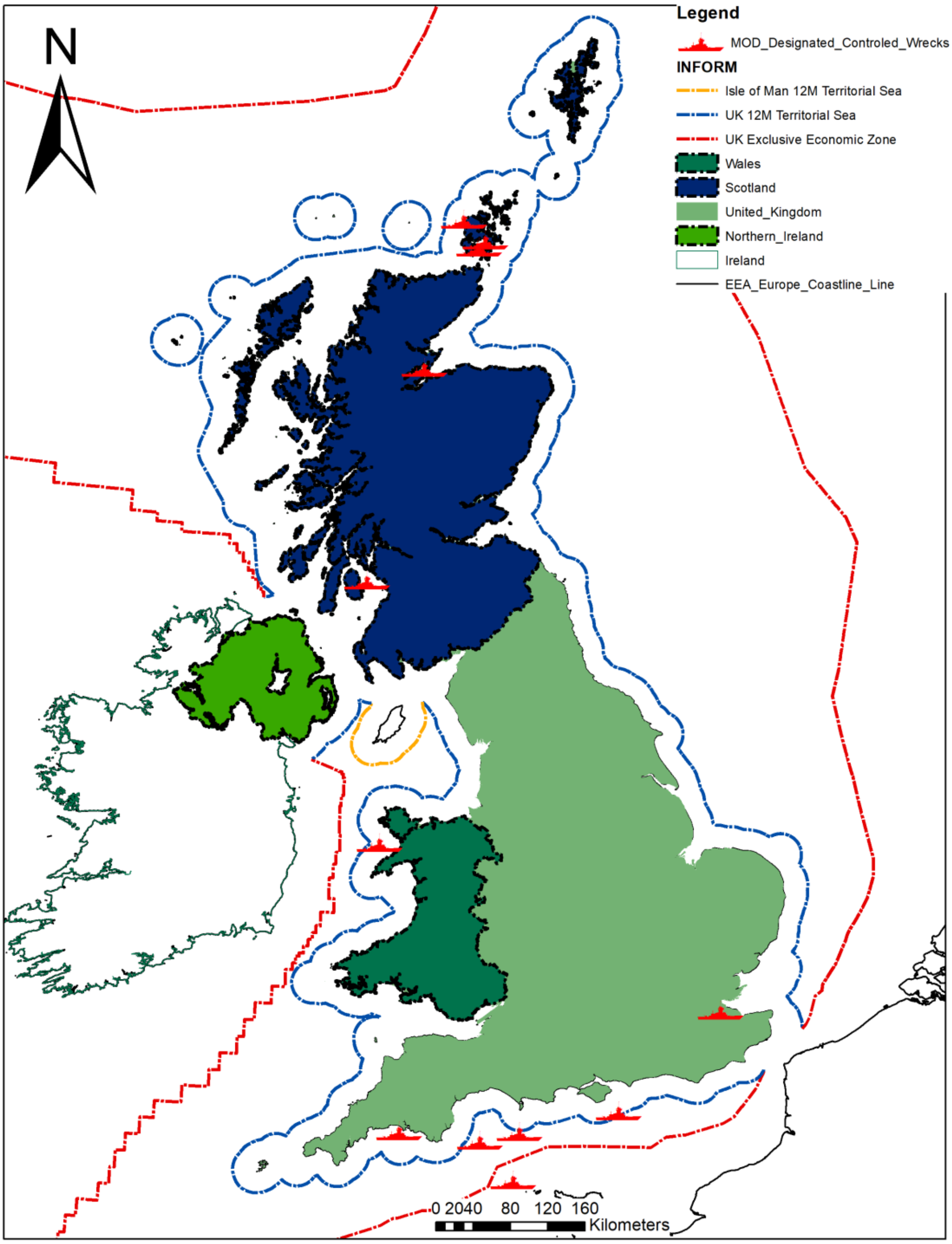

Figure 3. Controlled Designated Areas (MOD 2017) **by the MOD. The wreck locations are based on HE Maritime Protected wreck sites as in 2017 (HE Maritime 2017). The coastline is NGA** (National Geospatial-Intelligence Agency 2018)**, EMODnet** (EMODnet 2018) **and EEA** (EEA 2018)**. The UK Territorial Waters are plotted by EMODnet and continental Europe by the European Environmental Agency. The author of this thesis created the map of ArcMap 10.5®.**

1.3 Research Questions

This thesis is concerned with the accurate representation of the archaeological record and its surrounding environmental dynamics to understand the site formation process. Considering this, if we can only quantify or capture resolution to X level, how can we describe or interpret to Y level? A series of research questions emerged to answer this problem:

1. How can the integration of data from multiple temporal and spatial scales lead to an improved understanding of shipwreck site formation processes?

2. Does our understanding of the site formation processes of a wreck improve with pre- and post-disturbance surveys?

3. In what way does documenting with new technologies enhance our understanding of shipwrecks?

4. Is it possible to combine and compare datasets derived from different methodologies to understand 4D site development better?

1. 4 Aims and Objectives

1.4.1 Aims

The aims of this thesis are to investigate if the use of an integrated methodology to study site formation processes underwater can provide:

1. better archaeological results
2. better strategies for cultural heritage care

1.4.2 Objectives

In order to achieve the above aims, the objectives of this thesis are therefore:

1. To produce a temporal-geographical information system (t-GIS) model of the site formation processes on the selected shipwrecks (and their environments) combined with historical, archaeological and remote sensing data.

2. To create geo-referenced maps comparing the short, mid and long-term site formation processes.

3. To compare new high-resolution datasets with *in situ* archaeological observations to produce better-informed interpretations.

4. To provide new information on the current environmental dynamics to identify areas for potential future investigation, mitigation, and better management strategies.

5. To demonstrate the potential of fully integrated methodologies on submerged shipwrecks using multiple-scalar analysis on specific case studies (*Hazardous*, *Rooswijk,* and *Invincible*).

1.5 Case Studies

Thousands of submerged wrecks are potential case studies for site formation processes in a variety of environments around the world. However, each one requires locally focused research. Although it is an impossible task to address every wreck, it is vital to present localised research with a consistent methodology that can be applied to any context.

As such, an overview of the 53 Protected Wreck Sites in England (HE 2017b) was undertaken, describing their surrounding environments. The objective was to correlate their remains (coherent or scattered) with the energy of the environment (high, moderate, low) to create a classification based on this relationship[10].

This thesis does not aim to provide an exhaustive analysis of numerous shipwreck sites. Instead, it focuses on three case studies, which offer the possibility to understand shipwrecks in key environments on a multiple-scale: the *Hazardous,* the *Rooswijk*, and the *Invincible.*

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[10] Further explained in chapter IV.

It was decided to prioritise in-depth studies over a breadth of different examples to answer the aims and objectives of this thesis. By selecting only three sites to analyse, a more critical insight could be given to each, thus providing a more precise framework for the integrated methodology presented here.

The case studies selected for analysis were chosen with the following criteria in mind: data availability from previous work and the possibility to generate new data based on repeated survey and excavation on site to allow for the creation of a time-lapse to understand changes to the seabed environment and the wrecks themselves. Another primary criterion was the ability to have direct access to the archaeological sites by taking part in fieldwork during different seasons. Considering that, the state of preservation varies from site to site. Although, there is evidence of considerable decay on each ship's structure[11] and artefacts.

In order to carry out extensive research on wreck sites including desk-based assessment (DBA), survey, excavation, and post-excavation analysis, a combination of factors are required. It is essential to recognise that the practice of maritime archaeology in the field requires a team effort. Only through the combined effort of individuals, licensees, charities, governmental, navy and military institutions, as well as commercial and educational sectors of archaeology, was it possible to carry out further research and fieldwork.

1.5.1 *Hazardous Prize* 1699-1706

The first case study, the Warship *Hazardous Prize* Project Group (WHPPG) has carried out research on the wreck for over 30 years (Figure 4). Their research has been under former licensee Norman Owen (1988-1990) and the current licensee Iain Grant (1991-present). They led the combined efforts of volunteers, archaeological advisors and people from both the commercial and educational sectors. In 2017, the archaeological team had the opportunity to carry out an excavation, with the support and permit of HE. During this season WHPPG managed to carry out an extensive pre-disturbance survey and recover a few artefacts during the excavation. Unfortunately, the weather

[11] In the case of *Rooswijk,* is the absence of coherent ship structure.

restricted fieldwork on site. The excavation carried on during the summer of 2018, with a repeated survey on site, when the visibility conditions allowed it.

The *Hazardous* was a 50-gun fourth-rate ship of the line. She was built in Lorient, France in 1699, and was originally known as *Le Hazardous*. She was captured by the British Navy in 1703 and served mainly as an escort ship[12]. On September 1706, she was commissioned to escort a convoy of 182 merchant ships from Chesapeake Bay, in Virginia, to the Downs off Kent. However, a storm scattered the large convoy and left *Hazardous* with only 35 merchantmen that reached Lizard Point in Cornwall. Even after the tragic death of her Captain and some crewmembers due to illness, they decided to continue. On the 18th November 1706, another storm forced her to anchor in St Helen's Roads, in the Eastern Solent, overnight. However, a combination of bad weather and poor decision-making caused *Hazardous* to run aground in Bracklesham Bay on the 19th of November 1706 (Holland 2015:128–29; Maritime Archaeology Trust 2018; Owen 1988; Pascoe Archaeology 2018a; WHPPG 2018).

1.5.2 *Rooswijk* 1740

The second case study, the *Rooswijk* Project, is led and funded by the Cultural Heritage Agency of the Netherlands (RCE) in collaboration with Historic England (HE) and MSDS Marine Ltd as the diving contractor. This project planned an excavation season for 2017, including part of the archaeological dive team that excavated the wreck in 2005. Ken Welling (2005-present), the current licensee and the person who found the wreck in 1996, also collaborated with the team. However, due to logistical complications and poor weather conditions during that summer, it was decided to extend another fieldwork season during the summer of 2018.

The *Rooswijk* was built in 1737 in the *Vereenigde Oost-Indische Compagnie*[13] (VOC) shipyard, Oostenburg in Amsterdam. She had a successful maiden voyage from Texel to Batavia[14] from 24th October 1737 to 11th July 1739. However, her second attempt to make the same trip ended tragically. On 8th January 1740, she was caught in a storm on

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[12] *Le Hazardous* was classified as a third-rate in the French Navy, but after capture, she was catalogued as a fourth-rate in the British Navy. Also,

[13] Dutch East India Company (VOC)

[1414] Batavia is present day Jakarta, Indonesia. It was the capital city for the Dutch East Indies.

her way to Batavia that wrecked her on the Goodwin Sands. The calamitous event left no survivors, hence no records of the last moments of peril and despair before the *Rooswijk* was lost to the "ship swallower" [15] (Bruijn, Gaastra, and Schöffer 1979:458;506; HE, RCE, and MSDS Marine Ltd 2018; MSDS Marine Ltd 2018; PAS 2017:17; WA 2007). The absence of a historical record of her tragic loss left a blank canvas for archaeological interpretation of her last moments. Therefore, an integrated approach of the site formation processes is key in the understanding of the changes that the wreck has endured.

1.5.3 HMS *Invincible* 1744-1758

The third case study, the *HMS Invincible* Project, is led by Bournemouth University (BU) partnered with the Maritime Archaeology Sea Trust (MAST), and working in close collaboration with the National Museum of the Royal Navy (NMRV). This project was awarded a LIBOR grant[16] in 2016 by Her Majesties (HM) Treasury, enabling extensive excavations on site to be carried for at least two seasons (2017-2018), with a possible third (2019). The project builds upon previous efforts of the former licensee Jon Bingeman (1981-2006) as well as the current licensee Dan Pascoe (2006-present). Both licensees worked in the past with the support of volunteers, HE[17], University of Southampton (UoS), Nautical Archaeology Society (NAS), Maritime Archaeology Trust (MAT)[18]and MSDS Marine Ltd.

Invincible is a 74-gun third-rate ship of the line that was built in Rochefort, France in 1744. She was originally known as *L'Invincible* in the *Marine Nationale* (The French Navy), up to 1756 when the British Navy captured her off Cape Finisterre. *Invincible* had a short but successful service under the British flag until 1758. While attempting to leave anchorage from Spithead and head towards Newfoundland, Canada, *Invincible* suffered a series of calamities. Her misfortune combined with bad weather forced her to run aground and she was lost on Dean Sand, in the Solent. Her lines became the base

[15] The Goodwin Sands have been referred to as the ship swallower as early as 1570 (Larn and Larn 2002; Wessex Archaeology 2006c:5).
[16] London inter-bank offered rates (LIBOR) fines to be used to support military charities and Royal Voluntary Service.
[17] Formally known as English Heritage (EH).
[18] Formally known as Hampshire and Wight Trust for Maritime Archaeology (HWTMA).

of the design for the future generation of 74-gunships for the next 50 years. This type of ship became the backbone of the British Navy up to the battle of Trafalgar in 1805 (Bingeman 1985; Lavery 1988; Pascoe Archaeology 2018b).

1.6 Contribution

The three case studies presented in this thesis form part of a list of 53 Protected Wreck (PW) sites created by HE (HE 2017b) and only four of those are classified as Heritage at Risk (HAR), including *Rooswijk*[19] and *Invincible* (HE 2017b). Therefore, two of the case studies represent 50% of the wrecks that urgently require further understanding of their site formation process before they perish. Unfortunately, other protected wreck sites, such as *Hazardous*, require more attention but do not meet the criteria to be classified as Heritage at Risk by HE. This is despite the fact that *Hazardous* also presents considerable archaeological potential for research and is rapidly decaying.

On this rare occasion, during the summer of 2017 and 2018, *Hazardous, Rooswijk,* and *Invincible*[20] all carried out excavations, although all on different scales. For example, the *Invincible* and *Rooswijk* projects are the most extensive underwater excavations that have taken place in the past decade in British waters.

All three projects kindly allowed the author of this thesis to have access to the sites, their materials, archives, as well as to actively participate in fieldwork, enabling the thesis to include previous work and newly collected data from both surveys and excavations. This was crucial in the development of the thesis, as it allowed for new approaches to previous research and interpretations. The site formation process study of all three wrecks presented a variety of challenges. Therefore, to address their particularities, they are presented as individual chapters. However, their comparative study offers a productive discussion with a wide range of submerged wreck sites in Britain. By including first-hand information in this methodological study of shipwrecks and adding the personal experience out in the field, the archaeological interpretations

[19] Other two are *Stirling Castle* and *Northumberland* (1703), both wrecked during the Great Storm.
[20] With a final excavation season in 2019.

are handsomely enriched. In agreement with Dhoop (2016:56), an archaeologist learns best through practice.

It is often in the process of doing that hypotheses are formulated, tested, and then a synthesis takes shape or entirely new ideas emerge. As Adams explains, the way we experience shipwrecks not only leads to understanding the challenges of recording underwater, it also guides our understanding of complex structures through the *primacy of vision* (Adams 2013b:85–96), and most importantly how we transmit these ideas through explanation and interpretation.

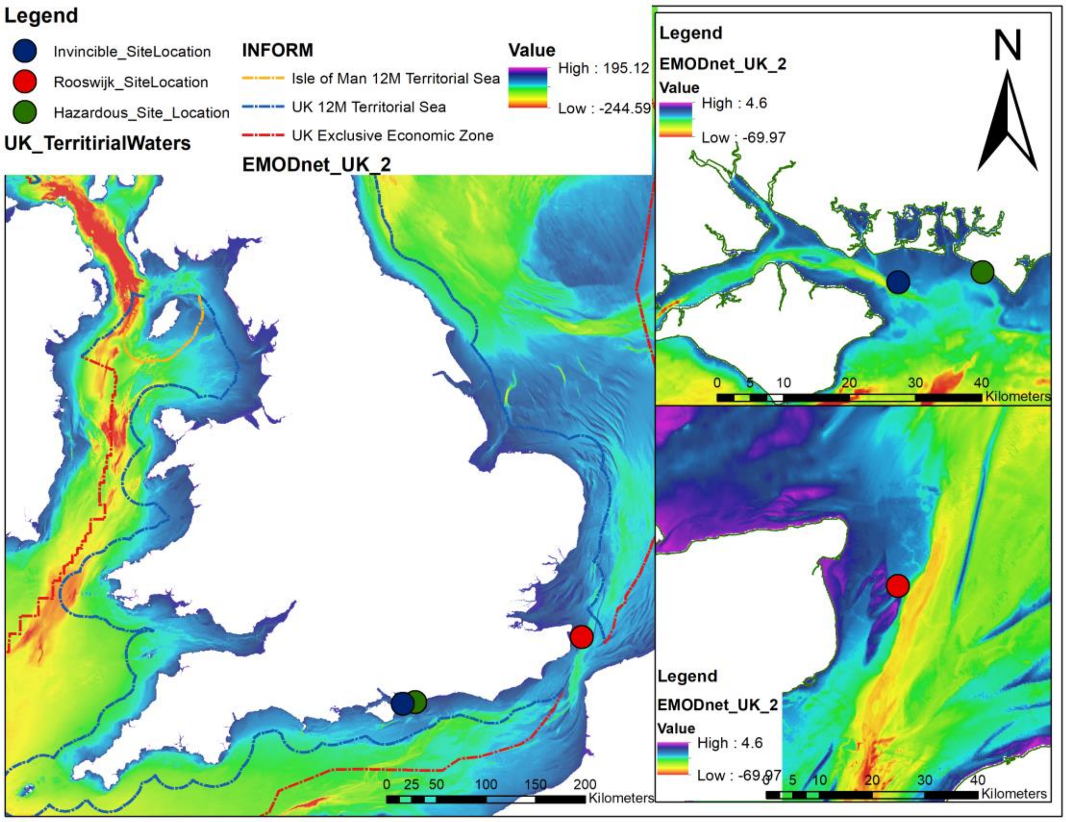

Figure 4. The site locations are taken from HE protected wrecks (HE 2017b)**. The projected coastline is the World Vector Shoreline (WVS) from NGA** (National Geospatial-Intelligence Agency 2018)**. The bathymetry and UK territorial waters are sourced from EMODnet** (EMODnet 2018)**. Maps created by the author on ArcMap® 10.5.**

1.7 Structure of Thesis

The introduction in Chapter 1 presents the core interests of this thesis by addressing the gaps in knowledge regarding site formation processes on submerged shipwrecks. In this section, the reader encounters a literature review of the most relevant sources and case studies, delineating the current state of research. This is followed by an explanation of the main contributions of this project. The chapter continues by presenting a broader context of a study on shipwrecks, emphasising the motivation behind the selection of the case studies.

Chapter 2 attends to the research history of underwater site formation processes, putting into context the development of techniques, methodologies and access to submerged sites. The chapter then focuses on the main theoretical framework and previous studies of site formation process studies on shipwrecks and its development within maritime archaeology. This section directs the reader to the essential concepts regarding shipwreck sites and relationships with their environments. Thus shaping the methodological approach for the case studies in the following chapters.

Chapter 3 presents a critical review of the materials, methods, and techniques used to study submerged shipwrecks and underwater cultural heritage in general. This chapter presents multi-scalar (space and time) methodologies with a flexible approach and a wide range of tools. The chapter explores some of the possibilities and limitations of the use of specific remote sensing techniques, with an explanation of the logic behind choosing or discarding specific techniques applied to specific wreck sites.

Chapter 4 delineates the challenges of site classification for shipwrecks in relation to their surrounding environments by defining the concepts and parameters used to link both. However, this chapter also provides a macro-scale analysis of the Protected Wrecks in the UK, focusing on those in England. This chapter sets the scene to understand the importance of localised research on specific case studies and the value of intra-site analysis.

The complexity of each site requires treating *Hazardous, Invincible,* and *Rooswijk* as separate case studies. The subsequent chapters (5, 6 and 7) all have a similar structure. They present summaries of the main research conducted at each site – they provide historical background, previous work on site and results of extensive DBAs, fieldwork seasons, and post-processing analysis in which the author was involved. However, the differences in methodology depend on access to data from previous work and the possibilities of generating new data, depending on the site conditions, project budgets, and equipment availability.

Chapter 5 presents the first case study, the *Hazardous* Prize that wrecked off Bracklesham Bay. This extensive shipwreck presents a coherent ship structure in rapid decay. The wrecking event is well documented, and previous archaeological work has focused on recording these changes with traditional means (Offsets, Direct Survey Method or Trilateration). However, the recent visits by the author (2017-2018) have produced extensive photogrammetric surveys, enabling cover extents of the site to be recorded accurately. This new information, aided by *in situ* observations, has radically changed the site formation process interpretation for this wreck.

In Chapter 6, the *Rooswijk* presents a completely different environment with a new set of challenges on the Goodwin Sands. The wrecking event has no historical record, leaving this open for archaeological interpretation. The *Rooswijk* is a scattered shipwreck, with no coherent ship structure found to this day. However, the abundant cargo of this VOC merchant vessel presents a distribution of artefacts from which site formation processes can be deducted. Therefore, in this chapter, the integration of multiple acoustic survey and positioning systems demonstrates its potential to plot the distribution of artefacts in relation to seabed movements. This is possible with a multibeam echo-sound (MBES) time-series correlated with the artefact distribution tracked by an Ultra-Short Base Line (USBL) system.

In Chapter 7 we go back to the English Channel, with the Royal Navy's first HMS *Invincible*, wrecked in the Eastern Solent. This case study allows the reader to immerse into a dynamic narrative of the archaeological record. Fortunately, *Invincible* is a well-documented shipwreck, historically and archaeologically, with an extensive, coherent structure.

The purpose of this chapter is to demonstrate the potential of integrating a time series multibeam echo-sound (MBES) with multiple image photogrammetry (MIP), and previous work on the site. The data integration provides a multiple-scale macro and intra-site analysis with *in situ* observations.

The results from the newly collected data were essential to understanding site dynamics as well as for re-interpreting previous archaeological work. The integrated methodological approach presented in this chapter provides valuable information to guide future research on site and management strategies.

Chapter 8 presents a discussion of the results of the case studies, using them as comparative explanation models. This critical analysis will enhance the contributions, weaknesses and future projections of truly integrated methodologies to understand site formation processes on submerged wrecks.

In this chapter, a productive discussion on underwater cultural heritage preservation and conservation is necessary. According to the UNESCO convention (UNESCO 2001), *in situ* preservation on shipwrecks should be a priority. However, some sites might benefit from minimum intervention, while others do not. Non-disturbance can sometimes be confused with site abandonment or abnegation when there is imminent risk of destruction unless proper recording and monitoring systems are in place. In the case of highly dynamic environments such as those found in British waters, frequent assessment should be a priority to guarantee the safeguard of submerged sites for future generations.

Also appropriate in this chapter is an extensive discussion of visualising methods with three-dimensional (3D) and four-dimensional (4D)[21] visualisation techniques for scientific analysis and public engagement.

This chapter summarises the newly gained knowledge on the shipwreck wrecks used as case studies, presented in chapters 5, 6 and 7, through pre and post-disturbance surveys. A final remark is made on future research and the impact this thesis can have for the study of shipwrecks.

[21] 4D refers to a 3D record with an added dimension of time, allowing to interpret change.

Chapter II. Research History of Underwater Site Formation Processes

This chapter provides a review of previous and current research that has focused on site formation processes emphasising on the importance of environmental dynamics on a macro-scale and on archaeological approaches on an intra-site scale. The chapter takes a historiographic approach to chart the development of techniques for site formation processes studies and highlights the effect this has had on archaeological results; thus improving our understanding of the study of submerged archaeological remains, specifically on shipwrecks.

The literature review presented in this section aims to contextualise the importance of data integration on multiple temporal and spatial scales within the discipline of maritime archaeology.

It does not, however, intend to provide a full history of the development of archaeology as a discipline, (See Trigger (2006), Johnson (2009)) or for a full review of maritime archaeology (See Adams (2013a)). Instead, it will provide a critical overview of key theories and trends that contributed to the definition of site formation process studies on submerged shipwrecks.

Further to this, the chapter will also present a critical analysis of submerged site care and management policies in the UK, focusing on the Protected Wrecks of England (PW). In doing this, the contribution of using integrated methodologies (such as the one presented in this thesis) for cultural heritage care and management strategies will be highlighted.

2.1 Underwater Pioneers

Before archaeology was considered as a mature scientific discipline, circa the middle of the 19th century (Renfrew and Bahn 1991:26; Trigger 2006:73–94), salvage on wrecks was a common practice. However, accessibility to these wrecks was a challenge limited by the lack of commercially available dive apparatuses. Nevertheless, as the technological capabilities of diving developed, access to these sites for a longer period became a reality and allowed direct observations to be made of shipwrecks and their environments. However, even in the advent of those developments there were still challenges to site accessibility, particularly in high-energy environments where divers confronted poor visibility and strong tides.

Modern diving has its origins in the development of a diving bell and later with the diving helmet, between the 1500s and 1800s. The first reference to a practical diving bell was made in 1531, when Guglielmo de Lorena dove in Lake Nemi to recover artefacts from the Roman galleys that belonged to Caligula (Marx 1991:31–32; Stewart 2011:27; US Navy 2016:3).

However, it was in the Solent, near to where the *Invincible* lies, that the Deane brothers patented diving dress: a major leap forward for surface supplied diving[22]. They adapted a smoke apparatus, used by firemen to move around burning buildings, by connecting to a helmet connected to surface pump and a protective suit (Marx 1991:53; Stewart 2011:112; US Navy 2016:4). This innovation allowed the Deane brothers to carry out salvage operations on the *Royal George*[23] (Figure 5) in 1832 and the *Mary Rose*[24] in 1836 (Bevan 1999a:112; Marsden 2003:21–23; Mary Rose Museum 2018). These were the first systematic salvage operations with*in situ* observation on shipwrecks, including the assessment of seabed sediment on the Mary Rose and the condition of rotten timbers on the *Royal George* (Bevan 1996:97, 114, 274; Booth 2007:7–8). Ultimately, this led the Deane Brothers towards the removal of sediment from sites and recovery of artefacts.

[…] *Mr Deane, ongoing down with his diving apparatus soon discovered it to be the muzzle of a gun, sticking upright in the mud, with 4feet above the bottom* (Bevan 1996:97; HampshireTelegraph 1835:407). *[…] when I commenced there was about 5 feet. I have removed 7 ft of mud and have every prospect of cleaning up the wreck* (Bevan 1996:114).

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[22] Siebe Gorman, made an improved neck seal from the diving helmet to the suit that increased safety considerably(Bevan 1999a:41). The Deane Brothers used this helmet for the *Royal George* and the *Mary Rose* salvage operations shortly after (Marx 1991:53–54).

[23] 100-gun First-rate ship of the line launched in 1756 in Woolwich. She was lost in 1782, while anchored at Spithead for repairs to the hull. The ship was heeled over carelessly making the guns to shift to one side, causing the *Royal George* to take water quickly and sink.

[24] The Mary Rose was built in Portsmouth in 1510, as the Flag Ship for Henry the VIII's fleet. She was tragically lost during a battle against the French, off Portsmouth in 1545.

Since the advent of the first operable diving equipment, archaeology has evolved into a scientific discipline, by broadening its methods beyond simply finding, collecting and recording artefacts. It has set out to find out more about the objects, the people who made them and to answer research questions with consistent methodologies and robust research models. The development of processual archaeology in the 60s and 70s arguably had a major role in reshaping our understanding of archaeological research. Processual archaeology aimed to develop methods for the understanding of the formation of the archaeological record and approaches to understanding past human behaviour for that record (Diaz-Andreu 2015:103). Innovation and technological changes such as remote sensing techniques (marine geophysics, satellite imagery, photogrammetry, laser scanning, global navigation satellite systems and acoustic positioning systems[25]) used in other sciences encouraged the discipline to integrate more scientific approaches. Whie this section aimed to provide a cursory insight into the developments of the discipline in relation to technological developments, the next section will provide a critical review of site formation processes.

[25] See further details in methods used in maritime archaeology in Chapter III.

Figure 5. This engraving represents Charles Deane during salvage operations on the Royal George in 1883. (Wallis 1883). The image was taken from Getty images and the letter labels were enhanced by the author. A) The Diver B) Led weight suspended from the helmet C) Air tube passing from the pump under the arm into the helmet D) Air Pump E) Signal Line F) Ladder for ascending and descending G) Floating buoy H) The middle deck of Royal George I) Main hatchway K) Lower deck L) Sloop M) the Isle of Wight.

2.2 Site Formation Processes

The central concern of this thesis is to examine the site formation processes of underwater shipwrecks through the use of integrated methodologies for producing higher quality archaeological results. This requires a systematic scientific approach that considers a critical review of how we understand site formation processes and the impact this has on strategies for cultural heritage care. This section explores the core concepts of site formation processes behind building the foundations for an adequate methodology.

Archaeology as with any other scientific discipline has deductive[26] (top-down) and an inductive[27] (bottom-up) processes to generate new knowledge. Admittedly, inductive reasoning is occasionally triggered by analysing the results that are generated by using or combining techniques, while exploring its capabilities and limitations. Therefore, a revolution of thought can be stimulated by the use of empirical methods and new technologies, as observed by Clarke (1972:17)[28] with computers being used in archaeology. The dialectic reasoning between theory and methods provides constant challenges for archaeologists dealing with material remains, thus, the methods used to investigate and analyse the archaeological record are under constant review. Merton pointed out that an empirical discovery may be the stroke of serendipity that compels a new theoretical direction (Merton 1968:157).

As archaeologists, we interpret the archaeological record to understand site dynamics and infer past human activity and social processes (Binford 1983). However, the data quality through which we understand these dynamics has a direct impact on our interpretation capabilities. Hence the importance of a continuous revision of our theory and methods (Adams and Rönnby 2013a).

In the 70s the Processual or "New" Archaeology principles of site formation processes became virtually synonymous with Binford's "middle-range theory" (Raab and Goodyear 1984:158). Binford (1977:7) wanted to develop ideas and theories regarding the formation processes of the archaeological record by classifying it as purely methodological in character as it allows archaeologists to deal with material records but not necessarily with problems of cultural dynamism (Raab and Goodyear 1984:260). Binford's archaeological approach to site formation processes diverts from the original purpose of middle-range theories in sociology, where Merton recognised and stated that abstract ideas do not necessarily lead to testable theories (Merton 1949:52). However, the nature of archaeological practice deals with material culture

[26] Deductive reasoning, or deduction, starts out with a general statement, or hypothesis and examines the possibilities to reach a specific, logical conclusion.
[27] Inductive reasoning makes broad generalizations from specific observations. There is data and then conclusions are drawn from that data.
[28] What at first appeared to be merely a period of technical re-equipment has produced profound practical, theoretical and philosophical problems to which the new archaeologies have responded with diverse new methods, new observations, new paradigms and new theory (Clarke 1972:17).

as a primary source, and thus requires testing of theories through case studies (artefacts, assemblages of artefacts or sites).

Binford recognised the urgent need for theory building on at least two levels. One level is what he referred to as a middle-range theory and the other as a general archaeological theory (Binford 1977:6). The middle-range theory involves abstractions, of course, but they are close enough to observed data to be incorporated in propositions that permit empirical testing (Raab and Goodyear 1984:257). Similarly, Muckelroy presented a bi-level (low-level and high-level of interpretation) of archaeological research to generate a new state of knowledge (Muckelroy 1978a:249). The theoretical lowest level deals with individual artefacts or an assemblage of them, then followed by an intermediate level, being a ship or a shipwreck as an individual site, while a high level of interpretation is when the archaeologist deals with the maritime culture (nautical technology, naval warfare and maritime trade and shipboard societies) (Muckelroy 1978a:226–30).

The position of this thesis differs and sees no further benefit of classifying site formation studies as a minor theory and more as part of the general archaeological theory. Instead, the analysis will consider a spatial and temporal scale of approach to understanding site dynamics. Here, the "lowest level" of analysis refers to the intra-site scale, which deals with the ship and its contents. The mesoscale analysis deals with the wreck site and the interaction between the environment and structural remains (coherent, elements, or absence) and the artefacts (scattered ordered or scattered disordered). The "highest level" is the macro-scale analysis that deals with the surrounding macro-scale environmental dynamics. Further interpretations of broader social questions (nautical technology, naval warfare and maritime trade and shipboard societies, dynamics in ports and harbours, etc.) will not be considered as a higher theoretical level, but instead as answering different research questions. Adams (2013b:47) pointed out that site formation processes lie in the realm of interpretation within a middle-range theory[29] (Gibbins 1990:377; Merton 1949; Raab and Goodyear 1998). However, this observation was made to distinguish that data collection was actually independent of the theoretical position of the individual who collected it. This is important to recognise as the data will be necessarily biased depending on the

[29] Understanding that middle-range theories are observational.

individual research agendas, methodology and postprocessing. Nonetheless, the data is based on the material record of a shipwreck and its environment, independent of whether we are able to represent it or not. The methods used to collect data will work as our glasses[30] through which we see the world; the theory will work as the guidelines for interpreting this information. As Schiffer pointed out, the only way of going back in time is through the archaeological record: the principles and procedures that we as scientists apply to material traces in the historical and archaeological records. If we desire to obtain views of the past that are closer to reality than those created by writers of science fiction, then we must build into our time machine a thorough understanding of formation processes (Schiffer 1987:364).

Harris (1979) presented his key work on archaeological stratigraphy, thinking of sites affected terrestrial environments. This is a core concept in archaeology that aids an understanding of temporality and the co-relation between assemblages of artefacts in the archaeological record. First, because most archaeological stratification is man-made and is not directly subject to the laws of geological stratigraphy. Secondly, because archaeological artefacts are inanimate; they are created, preserved or destroyed largely by human agencies (Harris 2002:8) or dynamic environments with biological, physical and chemical erosion. Furthermore, Harris pointed out the main laws of archaeological stratigraphy such as superposition, original horizontality, original continuity and stratigraphic succession (Harris 1979, 2002:29–39).
However, the dynamic nature of the sea and the nature of its sediments make stratigraphic excavations on shipwrecks much more challenging [31] . Very few submerged shipwrecks are excavated with a particular emphasis on its stratigraphy, such as the Mary Rose, due to time, budget or mainly environmental constraints (Marsden 2003). Shipwrecks with a coherent structure with compartments created by a complex architecture (partitioning's, decks, hatches, furniture or artefacts) form semi-closed areas with primary or secondary contexts[32]. Whereas a shipwreck without coherent structure, due to the wrecking process or post-depositional processes, is

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[30] Spectacles
[31]Further discussed in chapters V, VI, and VII, with the case studies and areas selected for this thesis: The English Channel (*Hazardous*), Solent (*Invincible*) and Goodwin Sands (*Rooswijk*), in the UK.
[32] See *Invincible* for a clear example in this thesis in chapter VII. Other extraornidary examples in the UK are the *Mary Rose, London, Sterling Castle,* and *Amsterdam.*

much more complicated to record and understand due to the disturbed stratigraphic layers[33]. Most importantly, the *Mary Rose* sank in a layer of thick mud and solid clay, which not only preserved the structure but also allowed a stratigraphic profile to be cut. Stratigraphic analysis in sands, silt or gravel are impossible to excavate in vertical sections (Green 2009). However careful *in situ* observations reveal details of the wrecking process and the post-wrecking (Gould 2000:53–57).

2.2.1 Site Formation Processes in Maritime Archaeology

Site formation processes have been a central concern in maritime archaeology in order to understand submerged sites, the research and application of which has produced numerous debates, publications of case studies and contributions on both a theoretical and practical level (Gibbs 2006; Holland 2015; Keith 2016; Martin 2011; Muckelroy 1978b, 1978a:157–214; Murphy 1997; O'Shea 2002; Ortiz-Vázquez 2013; Palma 2005; Quinn et al. 1998, 2007; Quinn and Boland 2010; Quinn and Smyth 2017; Stewart 1999; Ward et al. 1999). However, there is still space for contribution and critical analysis of techniques, methods and broader questions on the site formation process on shipwrecks. This section, therefore, presents a brief summary of key moments in the development of site formation processes theory in maritime archaeology[34].

It is important to recognise the first scientific efforts to understand underwater site formation processes of submerged archaeological sites on record. Before maritime archaeology was consolidated as a discipline, many explorers, intellectuals, and curiously minded people pushed the boundaries of what was accessible. One of the pioneers to observe differences between the natural environment and human-made structures was Reverend Odo Blundell's research focused on distinguishing the changes around crannogs (manmade islands) [35] (Barber and Crone 1993:520; Henderson 1998) to determine the elements that were artificially introduced. Blundell managed to gather a team of local canal divers and other reverends to survey the area and to look beyond the surface of the lochs (Figure 6). Although Blundell attempted to

[33] Such is the case on *Hazardous* or *Rooswijk* presented in chapters V and VI of this thesis.
[34] An extensive historiographic review can be found in Holland (2015:22–95).
[35] *Crannog* is commonly used to refer to any wholly or partly artificial island within a body of water.

provide an explanation of the changes that these crannogs went through, passing from a *systemic context* to an *archaeological context* (Schiffer 1972:157–58)[36], his research did not go further than this and was more descriptive than interpretative.

Nonetheless, his awareness of environmental characteristics, and *in situ* observations, were essential to describing and understanding the archaeological record[37].
Blundell compared the site conditions between Loch Ness, Bruiach, Lochy, Moy, Garry, Lundy, Oich and Treich and raised the awareness of differentiated sediment, slope, depth (water levels), storm, wind and waves. He focused mainly on the sediment accumulation of the silt that covered the wooden piles observed on *crannogs*.
Even though Blundell did not systematically analyse the same conditions on every loch, he addressed critical environmental factors for site formation processes. Further, he also cited that the freezing conditions (cryo-conditioning[38](Berthling and Etzelmüller 2011:382)) of some lochs had a direct impact on the timber; the wood would contract during winter and expanded again during spring, rapidly leading to decay (Blundell 1909b:16).

[36] Systemic context labels the condition of an element which is participating in a behavioural system or an active system, that the artefact or assemblage of artefacts is in use. This entailed part of the use-life processes: procurement, manufacture, use, maintenance, and discard.
An archaeological context describes materials, which have passed through a cultural system, and they have fallen out of use. They are now the objects of investigation of archaeologists.
[37] *The floor of the loch, which on the west side of the island was covered with verdure, was almost devoid of vegetation on the east side, the clay mud being nearly bare. Mud, however, it was, and not rock, for I repeatedly embedded my hand in it, though the clammy nature made considerable effort necessary to effect this* (Blundell 1909a:163–64).

[38] The interaction of cryotic (ice) surface and subsurface thermal regimes and geomorphic processes, as an overarching concept linking landform and landscape evolution in cold regions.

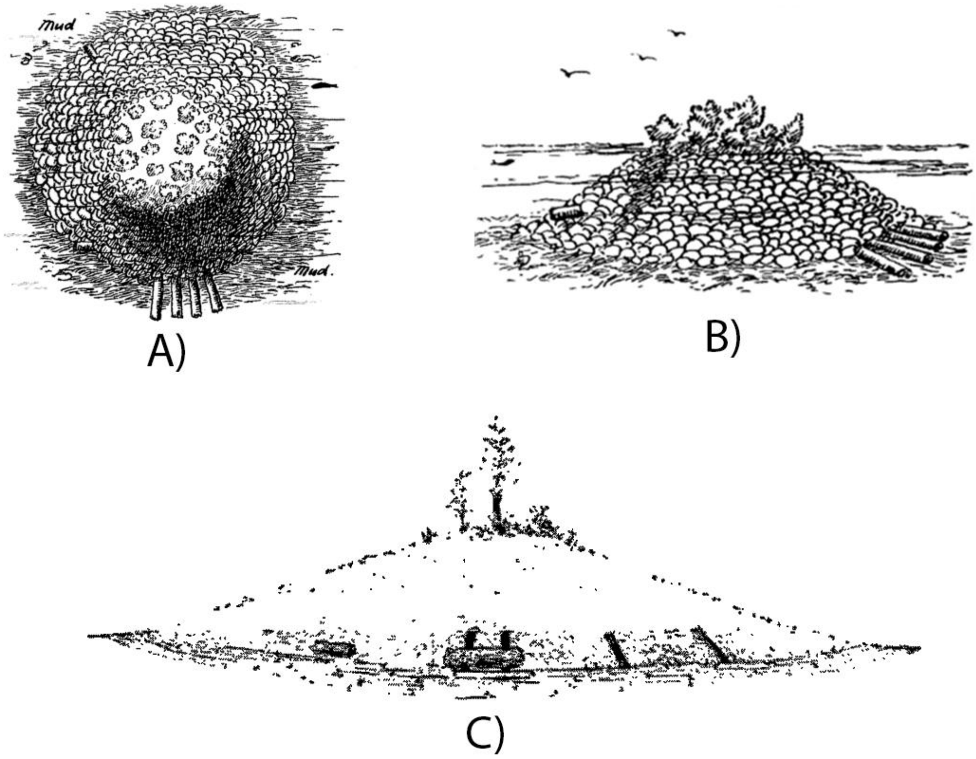

Figure 6. A) & B) Island in Little Garry Loch (Blundell 1909b:22) **and C) Crannog of Eilean Muirech, in Loch Ness** (Blundell 1909a:163)**. The sketches produced by Rev Cyril von Dieckhoff are used to illustrate the distribution of materials is subject to great artistic license, due to their recording methods, they do not have a scale, the orientation of or any sort of measurements.**

In the Mediterranean Basch (1972, 1973), Dumas (Cousteau and Dumas 1953; Dumas 1962, 1976), Van Doornick (Bass and Doorninck 1978; Bass and van Doorninck 1982), Bass (Bass 1968, 1980), Throckmorton (1965), Steffy (1975, 1981, 1985, 1994) and Frost (1973) drove the discipline and were without a doubt pioneers in the field. They recorded ships and started to take the next step into contextualising them on a broader historical scale: a boat or a ship became a part of a wider network of trade instead of an isolated find.

Dumas was the first to create a systematic shipwreck classification directly relating the environmental conditions to shipwreck remains, although he was limited to a few cases study exclusively from the Mediterranean region.
Dumas attempted to explain the state of preservation of wrecks by co-relating wrecking events with seabed slope, depth, and distance to shore. Further to this, Dumas highlighted the importance of the impact of local biological organisms and geological conditions as well as the post-depositional factors generated by rivers, rain and sea erosion (Dumas 1962:1–9) (Figure 7).

In an attempt to deconstruct the wrecking process of a ship, from the archaeological record, Dumas' explanation of the position of a the ship and its cargo, in relation to origin of a wreck or the "*genesis of a wreck*" is focused on three main aspects (Dumas 1962:9–12):

1. The travel dynamics of the sinking process, from the moment it leaves the surface to the seabed. Generally, one end of the ship goes down before the other at a more or less steep angle depending on cargo distribution and damage to the hull [This generates an impact force determined by the weight of the vessel and the velocity gained during the sinking unless she ran aground].

2. The scattering of the ship and its contents depends on the downward glide and its impact on the seabed. Including factors such as the nature of the cargo and the bottom characteristics [seabed topography and slope].

3. The disarticulation or scattering of the ships structure and its cargo. [Sea-bead characteristics, storm action, biological decay, sediment budget (erosion, deposition, and mobility)] [39]

It is clear that Dumas was aware of several factors that have a direct impact on the wrecking and post-wrecking processes of a shipwreck. However, his method lacked a systematic scientific classification system to co-relate these environmental characteristics with a ship's state of preservation.

[39] The author, using the terminology used on this thesis to explain the environmental characteristics that are analysed for the site formation processes, adds all the text in brackets [...].

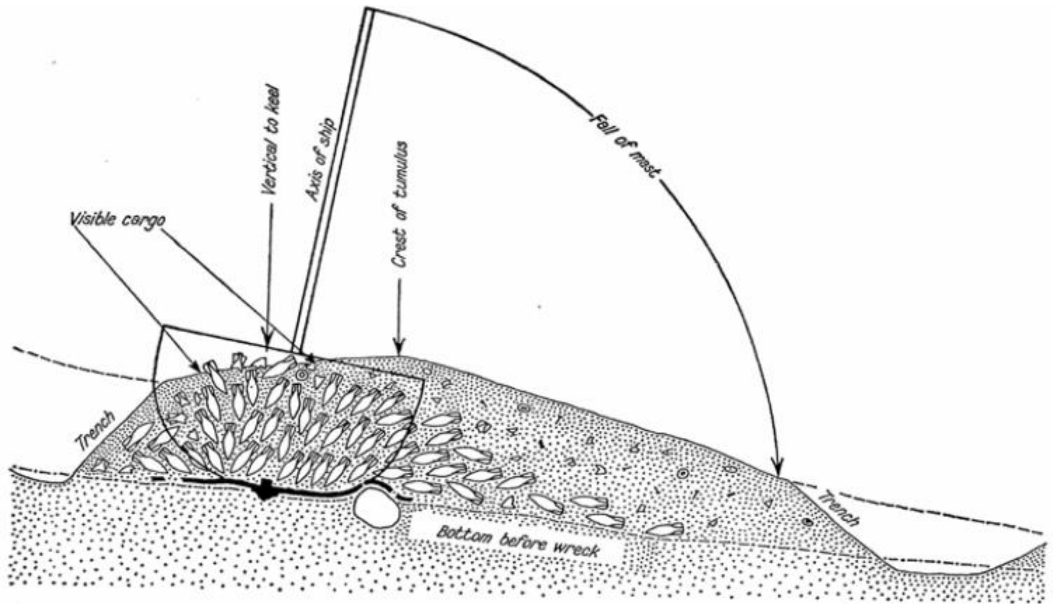

Figure 7. Schematic representation of the disintegration of wooden vessels (Dumas 1962:10)

Muckelroy, on the other hand, took the first step forward in having a systemic approach to the study of shipwrecks and their site formation processes. Muckelroy's theoretical background was strongly influenced by the emergence of processual archaeology or the "new archaeology" as stated by Clarke (1972:44). Muckelroy stated five essential principles during fieldwork that aid the scientific character of archaeology:

1. Problem-focused excavations
2. Area study and site system approach
3. Sampling considerations and methods
4. Pre-excavation and post-depositional model studies
5. Full use of scientific aids for location, processing, and analysis of sites and deposits, including fine sieving.

These principles are very much present in the outlay of this thesis as they are a central concern to answer questions about site formation processes. However, Clarke's (1972:44) division between computational, mathematical, quantitative, and model-based methodology results is outdated with newly integrated methodologies.

Muckelroy truly understood the values in the new scientific and multidisciplinary archaeology. As such, one of his major contributions to the field was to incorporate nautical archaeology with landscape studies whether they were submerged or not to form the broader concept of maritime archaeology. Subsequently defining the discipline as: "*the scientific study of the material remains of man and his activities at sea*" (Muckelroy 1978a:4).

Muckelroy managed to incorporate shipwrecks into a wider narrative of maritime activities, by delimiting and identifying overlapping areas of study within the discipline (Muckelroy 1978a:9–11) (See Figure 8):

A) Boats which are in an entirely non-maritime context (Graveyards)
B) Sites that are not submerged and evidence about shipping (Beached craft)
C) Drained areas that were initially underwater
D) Study of maritime technology
E) Seafaring aspects

And specifically excluding:

F) Sites that are not concerned directly with maritime activities, notably submerged land surfaces

However, the understanding of the limits within maritime archaeology and its specific study area has changed through time, and the "limits" of each area have indeed become less rigid and more inclusive (Figure 9). Research on submerged landscapes has demonstrated that they are not merely surfaces, and that localised maritime activities have been found associated with archaeological deposits (Bynoe, Dix, and Sturt 2016; Gaffney et al. 2007; HWTMA 2013). This provides an entirely new significance to the analysis of that area of study (F in Figure 8).
Another study area that Muckelroy neglected within maritime archaeology is the study of ports and harbours, whether they are on land or submerged. The study of ports and harbours provides a rich and diverse view of our maritime past, the routes of trade, the vessels of trade, systems of trade, as well as technology and maritime practice (Blue and Smith 2014) (G) (Figure 9)).

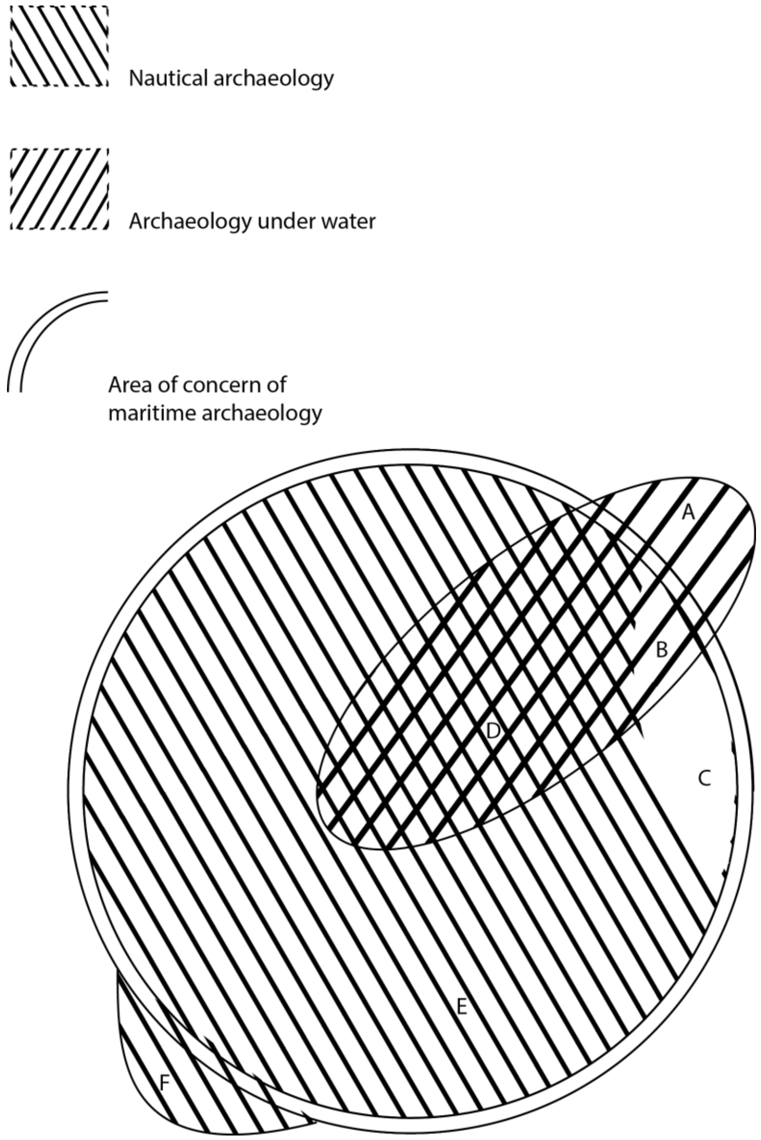

Figure 8. The diagram represents an area of study in maritime archaeology for Muckelroy (Muckelroy 1978a:9)**. A) Boats finds in non-maritime context, notably grave finds. B) Beached craft C) drained area sites D) Study of maritime technology E) seafaring aspects F) submerged landscapes**

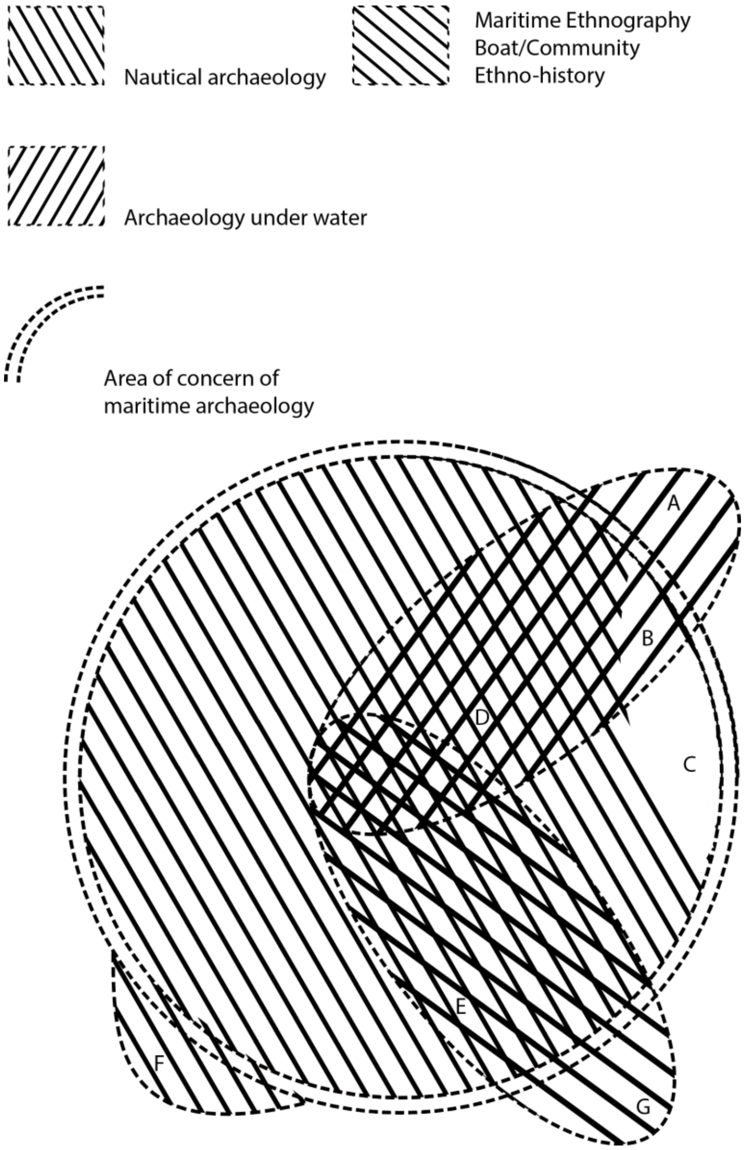

Figure 9. This diagram is made by the author, showing the areas of interest within maritime archaeology, based on (Muckelroy 1978a:9)**. A) Boats find in non-maritime context, notably grave finds. B) Beached craft C) drained area sites D) Study of maritime technology E) seafaring aspects F) submerged landscapes G) Ports and Harbours.**

In this view, maritime archaeology encompasses a wide range of topics, with considerable overlap with other disciplines or areas without confined boundaries between them (Figure 9). However, each environment requires specific methods to understand their particularities. Therefore, maritime archaeology has reached out to other disciplines such as history, anthropology, sociology, geography, oceanography, geophysics, geology, biology, chemistry, and physics, among other disciplines to understand the archaeological record better.

2.2.2 Site Formation Processes on Shipwrecks

Although site formation processes have been present in maritime archaeology since the early 60s (Dumas 1962), and later in terrestrial archaeology since the late 80s (Schiffer 1987), there is still a lot to be understood. Especially when we consider submerged wreck sites, with their extremely dynamic environments and infrequent monitoring that is carried out at intervals of only a few times a year at best. As Colin Martin aptly pointed out […] *no two wreck-site formations are the same, since the complex and interacting variables that constitute the environmental setting, the nature of the ship, and the circumstances of its loss will combine to create a set of attributes unique to each site* (Martin 2012:2). This uniqueness also requires site-tailored specific methods to record and understand the subtleties of the particular formation process.

The archaeological record undergoes successive transformations from the moment the remains participated in a *systemtic context* and later turned into *archaeological context* (Schiffer 1975:838). A *systemic context* labels the condition of an element, artefact or assemblage of artefacts which are participating in a behavioural system or an active asset (Schiffer 1972:157). An *archaeological context* describes materials which have passed through a cultural system, and which are now object of investigation (Schiffer 1972:172). In other words, an assemblage of artefacts such as a ship is in its *systemic context* while it is in use; while when it wrecks and it is abandoned it transforms into an *archaeological context* and forms part of the archaeological record. Once the object or assemblage of artefacts forms part of the archaeological record, then it is transformed by the interaction through time between culturally deposited assemblages (*c-transforms*) and the specific environmental conditions in which they were placed (*n-transforms*) (Schiffer 1975:838; Schiffer and Rathje 1973). The division between *c-transforms* and *n-transforms* has been extensively used for breaking down and explaining site formation processes of shipwrecks (Bass 1980; Dumas 1962; Muckelroy 1978a; Murphy 1997; Nesteroff 1972; Oxley et al. 2016; Stewart 1999; Throckmorton 1965; Ward, Larcombe, and Veth 1998; Ward et al. 1999). Gibbs and Duncan pointed out (2016:179) most studies of maritime site formation processes have concentrated upon the various natural (*n-transforms*) (Martin 2011; Stewart 1999; Ward et al. 1999) and to a lesser extent cultural processes (*c-transforms*) physically impacting the remains of the vessel and its cargo (the shipwreck) (Gibbs 2006; Oxley et al. 2016).

Muckleroy was the first to present a robust shipwreck evolution model in maritime archaeology that included natural and cultural processes (Muckelroy 1978a:157–59). His model represented the evolution of a shipwreck as a flow diagram comprising five subsystems or stages:

1) The process of wrecking
2) Salvage operations
3) Disintegration of perishables
4) Seabed Movement
5) Excavation methodologies

Muckelroy stressed the active nature of wrecks, with two key factors that would transform a site. Firstly, *extracting filters,* defined as mechanisms that took artefacts away from the wreck, such as the nature of the wrecking process, salvaging, and disintegration of objects (Muckelroy 1978a:165–69; Stewart 1999:567). Secondly, *scrambling processes* which rearrange patterns, that begin during the process of wrecking (such as discarded, abandoned, or lost salvage gear, structures, or even vessels as well as impacts on the environment and landscape)(Oxley et al. 2016:179). This included the post-depositional wrecking processes such as waves, currents, seabed movement, and biological weathering[40] (Muckelroy 1978a:169–82; Stewart 1999:567).

Muckelroy proposed a site classification system based on environmental characteristics. This typology of wreck sites ranked physical attributes such as topography, the particle size of the deposit, slope, sea horizon, and fetch. Although these attributes do not necessarily represent how the environment impacts on the wrecks, these categories became essential for understanding the taphonomic[41] formation process.

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[40] Biological weathering is the weakening and subsequent disintegration of rock by plants, animals and microbes.

[41] The natural processes (*n-factors*) which govern the trajectory of a wreck site from its initial wrecking to present day (e.g. burial, erosion, and redistribution of material) are defined here as the taphonomy of the shipwreck site. Differing to what Astley (2016:3) defines as ship-wreck tophonomy, where she includes the cultural processes (dreding, looting excavating, slavage, etc).

The system that Muckleroy proposed for understanding site formation processes was heavily influenced by Clarke's (1972:1–60) model-based approach to archaeology. Muckleroy explains that the whole shipwreck process constitutes a closed-system, *with the ship as input, and with a number of different outputs*, *about which there are varying degrees of knowledge* (Muckelroy 1978a:159) (Figure 10). In other words, this system-based approach was like a box that encompasses the site formation processes surrounding a ship and our understanding of the elements are a product of this "methodological box or system".

Determining to what degree a shipwreck is semi-closed or an open system [42] is complicated and raises debate[43]. From a large-scale and long-term perspective, Quinn (2006) understands wrecks as open systems. However, on an intra-site scale, it has been observed that they also act as semi-closed systems when several artefacts are buried at the same time and form an undisturbed primary context (Gregory 2012). Ultimately, all wrecks are open-systems, as they will eventually decay and perish with time. Nonetheless, shipwrecks go through periods of disturbance, disequilibrium, and stabilisation or equilibrium with their environment (Astley 2016:18; Quinn and Boland 2010). It has been observed that wrecks fluctuate from an open system to semi-closed systems reaching temporary periods of stability. These systems have a dynamic interaction with their surrounding environment and are also subject to cultural processes, therefore it must take into account both *extracting filters* and *scrambling devices* (Muckelroy 1978b:165–75). Therefore, it is important to understand both macro, meso and intra-site levels of site formation processes on shipwrecks, through surveys and archaeological excavations as it argued throughout this thesis.

[42] Shipwreck considered as open systems present a continued flow or exchange of materials (sediment, bio-matter, water, artefacts) and energy (wave, tidal, storm).
[43] Wrecks that have undergone some kind of perturbation, whether natural or anthropogenic during their observation period acted as *open systems*, either gaining or loosing material to the surrounds. Whereas, those wrecks where the environmental conditions remained near-constant did not lose or gain material with their surroundings, so acted as *closed* systems (Astley 2016:271).

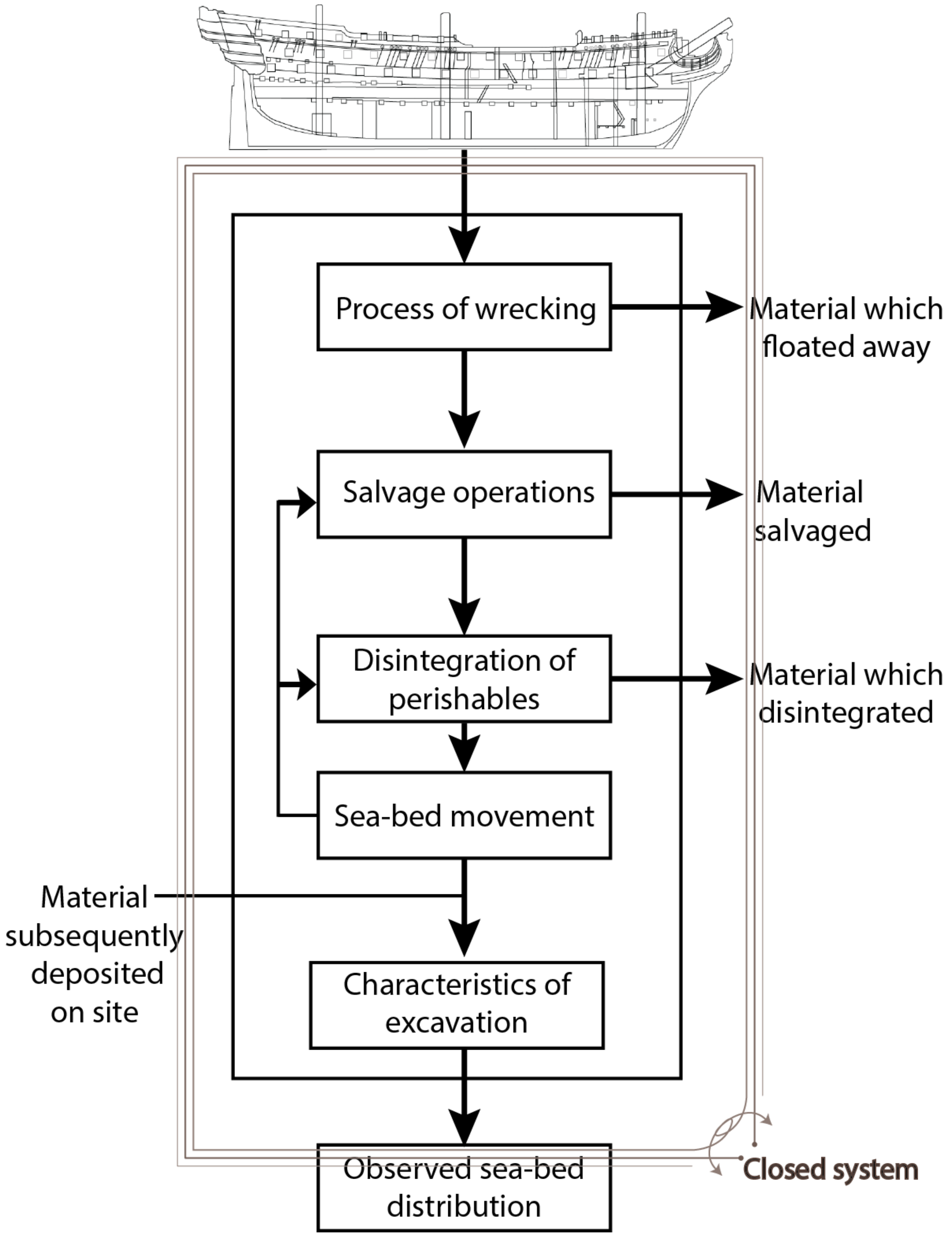


Figure 10. The illustration was created by the author based on the flow diagram representing the evolution of a shipwreck shown in Muckelroy (1978a:158).

Some of the macro-scale studies have more scientifically led approaches to understand the *n-factors*, concerning site deterioration models. Their research is mainly focused on quantifying and exploring a broad scale deterioration of a wreck site (Ferrari and Adams 1990; Ford et al. 2016; Gregory 2015). While others have a specific analysis that Muckelroy and later on others provide on an intra-site level that is essential for site interpretation (Adams 1990, 2013a; Adams and Rönnby 2013b; Bass 2012;

Batchvarov 2016; Eriksson 2013; Hocker et al. 2013; Marsden 1972, 2003; Martin 2017, 2005; Rönnby 2013; Rule 1982).

Gibbs (2006) and Duncan (Gibbs and Duncan 2016) presented a comprehensive shipwreck site formation flow diagram that included more *c-factors* than Muckelroy (1978b:158) had originally accounted for (Figure 11).

Gibbs (2006) and Duncan (Gibbs and Duncan 2016) placed emphasis contextualising the historical background of the ship to aids in understanding the pre-impact events of a vessel (Figure 11). This provides information on what to expect to find on the seabed. In a sense, the ship's life story is utilised as a diagnostic tool, used in a similar way to when a doctor examines a patient. A doctor digs into personal and family history to understand symptoms, or signs of a potential injury, disease, or illness. In this fashion, the ships life story is fundamental for understanding its wrecking process and, later, its site formation process.

Gibbs and Duncan's flow diagram presents a flexible open-system with more possible outcomes that include different types of salvage, jettisoning, jetsam/lagan, as well as survivor and salvage camps (See Figure 11). Gibbs' approach on salvage suggests making a distinction between modern salvage and salvage in antiquity (Keith and Simmons 1985). While McCarthy added to identifying more cultural factors, by emphasising an important distinction between primary salvage and secondary salvage: […] *primary salvage being the recovery of materials by their owners, operators, or agents, presumably close to the time of wrecking, while secondary salvage is the modern recovery of materials by professional salvors or sports divers* (Gibbs and Duncan 2016; McCarthy 2001)[44]. Both types of salvage are categorised and supplemented by making the following distinctions (Gibbs and Duncan 2016):

1. Pre-impact actions
2. Crisis salvage
3. Survivor salvage
4. Systematic salvage

[44] This is relevant for the case studies presented in the thesis, having both primary and secondary salvage on the wrecks.

5. Opportunistic salvage

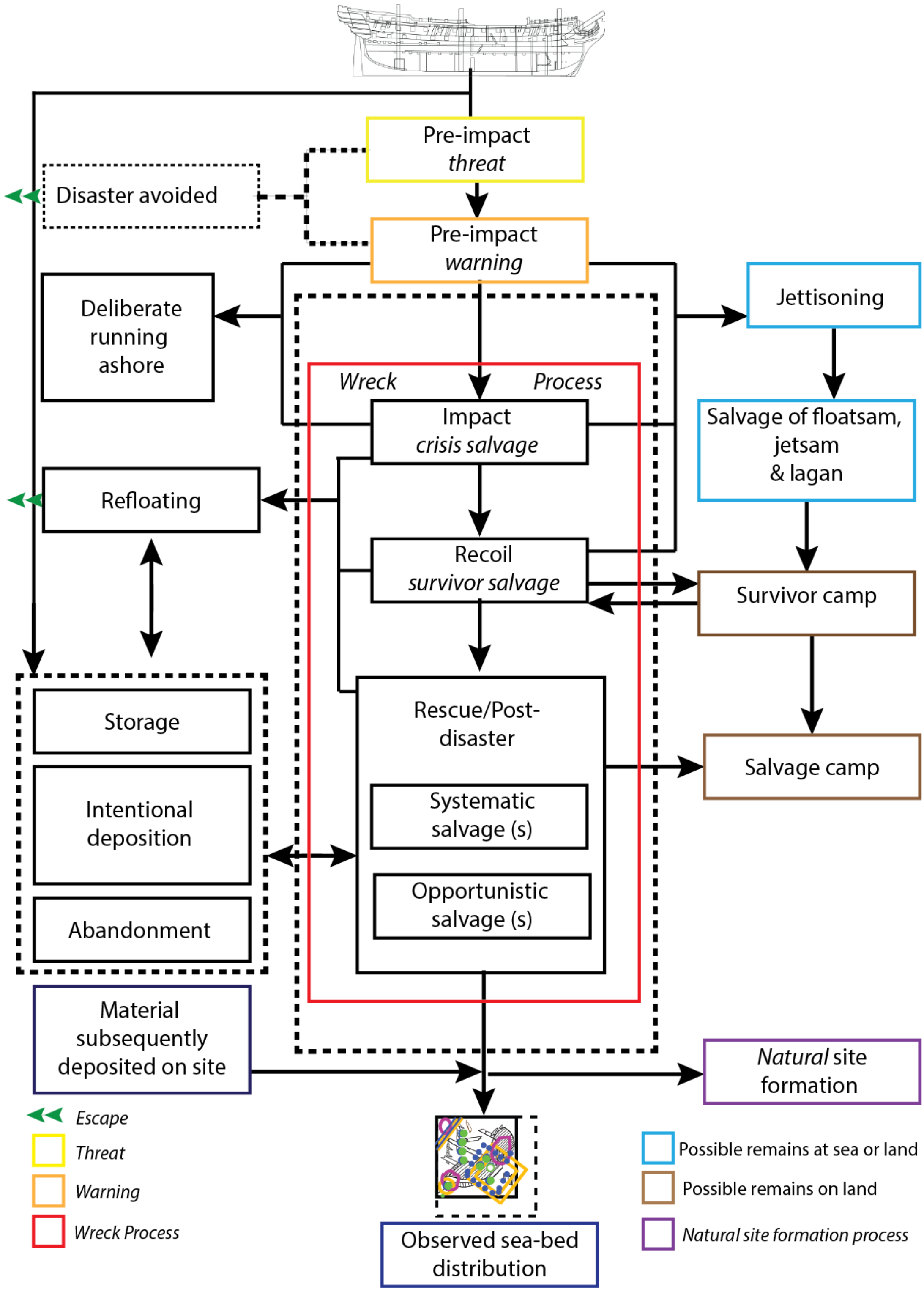
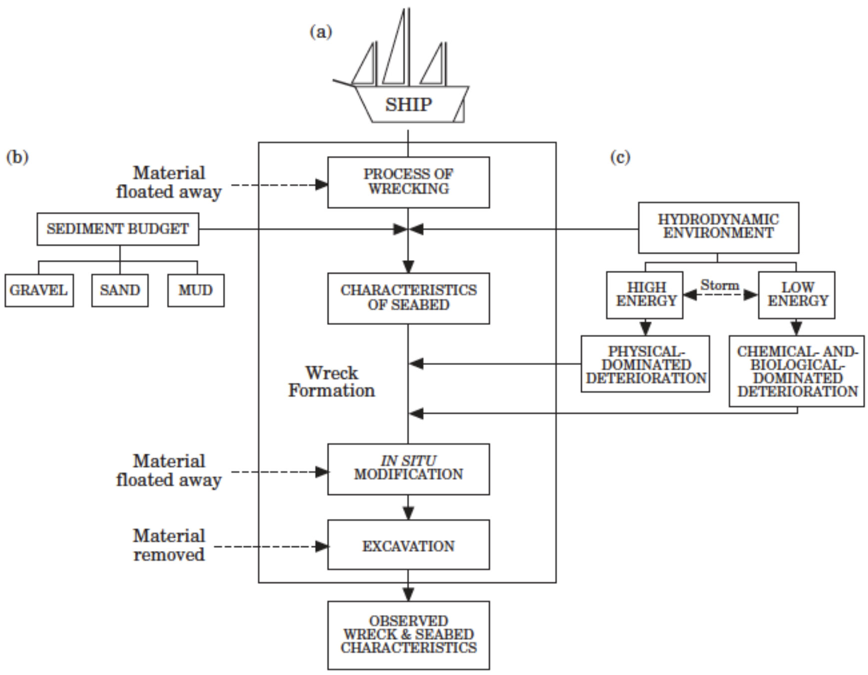


Figure 11. This flow diagram was created by the author based on the wrecking process presented by Gibbs (2006:13; 2016:183)**.**

Ward et al. (1999) explained Muckelroy's (1978a:158) model, by adding in more, *n-factors* that affect shipwrecks (Figure 12). The flow diagram was divided into three phases:

a. Ship (the process of wrecking[45])
b. Sediment budget
c. Hydrodynamic environment.

In the model presented by Ward *et al.* (1999), the sediment budget[46] and the hydrodynamics of the environment have a direct input immediately after the wrecking process. Furthermore, the *in situ* modifications and possibly excavations later also affect the wreck or artefact assemblage observed on the seabed. The sediment budget was defined as the rate of net supply or removal of different types and sizes of sediment grains to the wreck area (Ward et al. 1999:564). Furthermore, Ward et al. (1999) include the hydrodynamics by sub-classifying the environments into high or low energy[47], dominated by either physical or chemical and biological erosion (Figure 12). This environmental classification was overlooked by Gibbs (Gibbs 2006) and Duncan (Gibbs and Duncan 2016:183) by simply adding the *natural* site formation processes at the end of the flow diagram.



45 With a simplified wrecking process that was extended further by Gibbs (2006:12) and Duncan (Gibbs and Duncan 2016:183).
46 Sediment budget is defined as the rate of net supply or removal of different types and sizes of sediment grains to the wreck area (Ward et al. 1999:658).
47 Only focused on the storminess (wind and waves). Further explained in Chapter IV (Classifying shipwrecks and their environments).

Figure 12. The flowchart shows *n-factor*, or environmental factors (Ward et al. 1999:564).

A full perspective of site formation processes encourages breaking down the artificial separation between the wreck and its environment by including both natural (*n-factors*) and cultural processes (*c-factors*).

This thesis therefore presents an expanded site formation process diagram flow based on Muckelroy (1978a:158), Ward *et al.* (1999), Gibbs (2006:13), and Duncan (2016:183) (Figure 13). Considering that the wreck will act as an open-system (Quinn 2006) the natural formation processes should englobe the moment the wrecking event started to the present. As the environmental conditions of the moment of the wrecking event or impact will determine the post-impact state of preservation (Figure 13).

The proposed model expands further into environment energy dynamic and wreck classification instead of only having a hydrodynamic environment[48] input during the wreck formation process (further explained in Chapter IV).

A complete understanding of the dynamic environments of shipwrecks is required to bridge the gap between macro-scale[49] environmental interpretation and intra-site scale studies. The complexity of recording in these dynamic marine environments requires holistic methodologies to shape how we understand the archaeological record (Lucas 2011)[50]. Once we have a better understanding of the site formation processes of the wreck then the comparative analysis between other sites provides a new perspective on the cultural heritage care strategies.

[48] Only High and Low energy environments, dominated by physical erosion or chemical and biological (Ward et al. 1999:564).

[49] It is critical to understand the macro-scale analysis that offers a broad perspective to localised phenomena of site formation processes (explained in Chapter 4).

[50] Explained in Chapter III.

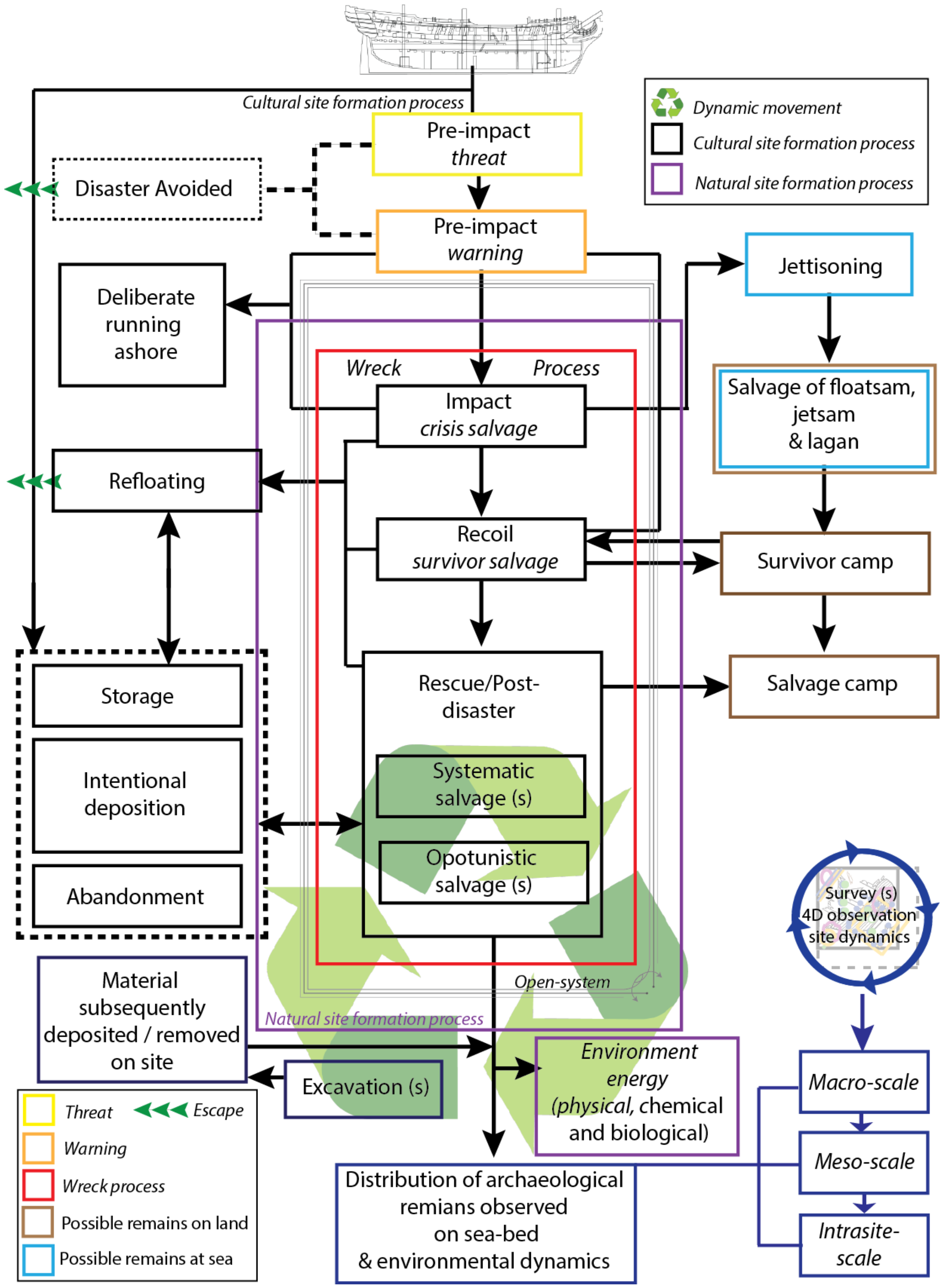


Figure 13. Expanded flow diagram of site formation process based on Muckelroy (1978a:158)**, Gibbs** (2006:13; 2016:183)**, Ward** (1999:564) **created by the author of this thesis.**

2.3 Cultural Heritage Care of Shipwrecks in the UK

This thesis' main aim is to present an integrated methodology that will produce higher quality archaeological results as well as provide a critical view of how we understand shipwrecks and their site formation processes. The immediate impact of this research methodology will be on the wrecks chosen as case studies the *Hazardous*, *Rooswijk* and *Invincible*[51]. However, it is crucial to place things into perspective and see the wider picture of the impact on other sites. This generated new questions for this thesis:

1) Should we consider multiple scale analysis of site formation processes for better strategies of cultural heritage care?
2) How would a macro-scale approach with a wreck classification system linked to its environment provide a good proxy to plan better strategies of cultural heritage care?

To answer these questions this section presents a critical analysis of cultural heritage care and management policies for historic shipwreck sites in the UK.

There are over 60,000 wrecks estimated around the UK (Cant 2013), of which only 68 have been designated as protected wreck sites in the UK (England: 53, Scotland: 8, Wales: 6, and Northern Ireland: 1) under the Protected Wrecks Act (1973)[52], and the Marine Protected Areas (MPA) (Historic Environment Scotland 2016) due to their exceptional historical value[53]. However, this section will only focus on the Protected Wrecks in English waters because the intention here is to highlight the complexly of multiple-scale methodologies to understand site formation processes on shipwrecks, so is not necessary to include all of the above-mentioned wrecks. By focusing on the Protected Wrecks of England it is possible to narrow down the vast information and specific strategies for cultural heritage care on multiple-scales (macro, meso and intra-site). The integrated methodology of this thesis offers the possibility of contributing to shipwreck management strategies by providing better archaeological interpretations.

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[51] Chapters V, VI and VII
[52] As of 1 November 2013, section 1 of the Protection of Wrecks Act 1973 has been repealed in Scotland. Sites previously designated under this legislation have been designated as Historic MPAs under the Marine (Scotland) Act 2010, or de-designated altogether (Historic Environment Scotland 2016).
[53] Further explained in section 1.2

However, it is important to recognise that the complexities of managing shipwrecks involve different organisations and government departments with distinct responsibilities and interests; although these overlap regarding wrecks on the seabed, the interests of the different sectors do not always align (Firth 2018:1)[54].

Within the institutions involved with the use of the sea academic institutions, commercial archaeology companies, museums, charities and volunteer-based projects play a critical role in research and UCH care. Pushing the boundaries of research and having capacity building strategies during projects has an immense impact on how we understand and look after our UCH. For example, integrated methodologies such as the one presented in this thesis can have a direct impact for better cultural heritage care and management strategies by exploring its capacities and limitations during fieldwork. This was possible through the collaboration of academic research (Bournemouth University and University of Southampton), commercial archaeology (Pascoe Archaeology, MSDS Marine Ltd and MAST) volunteer based worked (NAS and Hazardous Project) and heritage management organisations (HE, RCE and RNM). Therefore, it is important to acknowledge the importance of having an active role in cultural heritage care strategies by promoting archaeological research that involves different stages: documentation, fieldwork (surveys and excavation), conservation, site management plans, dissemination and publication.

An active role in cultural heritage care should promote pre-disturbance and post-disturbance surveys with integrated methodologies (historical sources, previous work, remote sensing techniques and *in situ* observations[55]).

Passive archaeological research can be confused by site-abandonment, justified by prioritising *in situ*[56] preservation instead of having active participation with fieldwork. It is critical that as archaeologists' we create awareness that UCH is constantly threatened by *c-factors* and *n-factors* and that wrecks are a finite resource.

2.3.1 International Regulations and Treaties

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[54] Heritage; Fishing; International interest; Public and environmental risk; Commemoration; Sea-use; Nature conservation; Ownership and recovery of wrecks; Navigation safety and wreck removal/dispersal; Recreation.

[55] See Chapter III for further detail

[56] *The preservation in situ of underwater cultural heritage shall be considered as the first option before allowing or engaging in any activities directed at this heritage.* (UNESCO 2001:3).

The world oceans comprise approximately 70% of the Earth's surface and they contain around 97% of its water (NOAA 2019; USGS 2019). As much as 40% of the world oceans are heavily affected by human activities, including pollution, depleted fisheries, and loss of coastal habitats (UN 2019c); directly affecting our UCH. Therefore, our oceans require regulation for adequate management as well as to avoid conflict between nations over both natural and cultural resources.

The United Nations Convention of the Law of the Sea (UNCLOS)(1982b) [57] defines the rights and duties of national states with regard to the use of the seas. UNCLOS set out to establish a legal order for the seas and oceans which facilitates international communication with due regard to the sovereignty of all States. This convention also promotes the peaceful uses of the seas and oceans with equitable and efficient utilisation of their resources; encouraging the conservation of their living resources as well as the study[58], protection and preservation of the marine environment (UN 1982b, 2019a, 2019b).

The legal status of the territorial sea and contiguous zone delimitation is critical for the organisation of managing marine resources, including UCH, that encompasses air space, the seabed and subsoil (Article 2 UN 1982b:27):

1. *The sovereignty of a coastal State extends, beyond its land territory and internal waters and, in the case of an archipelagic State, its archipelagic waters, to an adjacent belt of sea, described as the territorial sea.*
2. *This sovereignty extends to the air space over the territorial sea as well as to its bed and subsoil.*
3. *The sovereignty over the territorial sea is exercised subject to this Convention and to other rules of international law*

[57] To establish, with due regard for the sovereignty of all States, a legal order for the seas and oceans which will facilitate international communication, and will promote the peaceful uses of the seas and oceans, the equitable and efficient utilisation of their resources, the conservation of their living resources, and the study, protection and preservation of the marine environment (European Union 2019).
[58] Encouraging scientific projects with international cooperation such as The European Marine Observatio and Data Network (EMODnet) (EMODnet 2019)

The legal protection that UCH is afforded by each State, therefore, will depend on its location within the limits of the States territorial sea: *Every State has the right to establish the breadth of its territorial sea up to a limit not exceeding 12 nautical miles* (Article 3 UN 1982b:27).

The jurisdictional regime of UNCLOS (Article 303 UN 1982b:136) is fundamental for the organisation of States' territorial seas, establishing the boundaries of the protection of national resources and heritage at sea. The law of the sea, codified in UNCLOS, *supplies the jurisdictional framework pursuant to which States may, individually and cooperatively, develop a substantive law of* [maritime] *archaeology* (Oxman 1988:355). The UNESCO[59] convention of 2001 is intended to enable States to better protect their submerged cultural heritage while working in harmony with UNCLOS (1982a). The UNESCO convention (2001) is composed of the main text and an annexe, which sets out the "rules for activities directed at underwater cultural heritage". It aims to provide a detailed State cooperation system and provide widely recognized practical rules for the treatment and research of underwater cultural heritage. There is a great debate whether the UK should ratify the UNESCO convention (2001) or not, though the UK is a ratified state party member of the UNCLOS (UN 1982b) since 12th January 1998[60].

A close examination of the implementation of the UNESCO Convention (2001) reveals some of the problems and successes in each state party. For example, MacKintosh argues that if the UK does not ratify the UNESCO Convention (2001), then its position can become increasingly isolated and irrelevant. Without ratification, the UK will be unable to influence how the new global standard is implemented; and the UK will remain largely incapable of offering effective protection to wrecks of UK origin lying beyond its own waters (MacKintosh 2018:314).

The UK plays a leading role with global impact in maritime archaeology for its innovation in research, theory, methods and techniques to record UCH. There is a healthy archaeological community that works in close cooperation with governmental

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[59] United Nations Educational, Scientific and Cultural Organization
[60] The United Nations Convention on the Law of the Sea (UNCLOS) entered into force in 1994 and has since been ratified by about 160 states, including all the Member States of the EU and the EU itself (UN 2019a, 2019b).

institutions[61], academic[62] and commercial archaeology organisations[63], volunteer groups[64] and international organisations[65]. However, the protection of UCH in the UK is not perfect, nor is it anywhere else. Each nation or country has its own set of problems that are sometimes even shared between State parties. Hence, a critical review of some international policies, treaties and practices is always beneficial for the protection of cultural heritage and to develop better strategies. For example, legislation in the British overseas territories (BOT)[66] varies noticeably (Ministry of Defence 2010:2). The BOT extends around the globe and comprises almost 13,500 nautical miles of coastline and 480,000 nm^2 of land mass (as against 11,000 nm and nearly 72,000 nm^2 for the UK and Crown Dependencies). Within that extensive territory the UCH potential in the territorial waters of the BOT is greatly overlooked by legislation in the UK[67]. Further revision of unifying strategies for the care and management of UCH in the BOT with the UK is needed. Possibly through the ratification of the UNESCO Convention on the Protection of the UCH (2001) or alternatively a new convention of the BOT territories that could work in harmony with UNCLOS.

In sum, ships, boats and aircraft are of mobile nature. The place where they wreck can be determined by numerous factors, such as trade routes, bad-weather conditions, exploration, war, misfortune, poor seafaring skills or negligence to mention a few. Therefore, UCH will be subject to different policies, legislation, practices, as well as localised site formation processes (*c-factors* and *n-factors*). Furthermore, the European

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[61] To mention a few, Historic England (HE), Historic Engalnd (HE), Historic Environment Scotland (HES), Welsh Government's historic environment service (Cadw), Management Organisation (MMO), United Kingdom Hydrographic Office (UKHO) and Ministery of Defense (MOD).
[62] Examples in this thesis, Univeristy of Southampton and Bournemouth University.
[63] Examples in this thesis, MSDS Marine Ltd, Pascoe Archaeology (PA), Nautical archaeology Society (NAS), Maritime Archaeology Sea Trust (MAST), National Museum of the Royal Navy (NMM), Wessex Archaeology (WA) and Maritime Archaeology Trust (MAT).
[64] Examples in this thesis, The Hazardous Project
[65] The Cultural Heritage Agency of the Netherlands (RCE).
[66]Anguilla, Bermuda, British Antarctic Territory (BAT), British Indian Ocean Territory (BIOT), British Virgin Islands (BVI), Cayman Islands, Falkland Islands, Gibraltar, Montserrat, Pitcairn, Henderson, Ducie & Oeno Islands, Saint Helena, Ascension and Tristan da Cunha (including Gough Island Dependency), South Georgia and the South Sandwich Islands, Sovereign Base Areas (SBAs) Akrotiri and Dhekelia (on Cyprus), and Turks & Caicos Islands (Ministry of Defence 2010:2).
[67] See further detail see Chapter IV, in section 4.2.3.

seapower States[68] of the modern world (post-1492[69]) that encouraged globalisation have left an impressive archaeological record throughout the world, from small artefacts or assemblages of artefacts (wrecks) to ports, towns and cities.

The implementation of integrated methodologies at multiple levels (macro, meso and intra-site) along with holistic management policies, which go beyond a single States' territorial waters, will provide better strategies for the care of cultural heritage on a global scale.

Chapter III. Methodology

All methodological approaches to understanding a shipwreck site face the same reality: the survey will partially record the state of the wreck at a fixed moment in time. The frequency to which these surveys are carried out and the resolution of the data will have a direct influence on how we understand the wreck. However, by combining techniques on multiple scales, we achieve a better model to aid our understanding of the wrecks and interpretation of the site formation processes.

The methodology presented in this section aims to be a robust and general model that provides analytical tools to understand the site formation process on any class of underwater wreck site. This section includes a variety of sources that have been critically analysed and re-processed to answer this thesis' questions relating to site formation processes. The methods and technique presented in this section were chosen based on the research questions (section 1.3) that define the scale of the study. The macro-scale approaches are focused on understanding broad environmental dynamics (submerged or not). A medium or meso-scale examination is focused on specific wreck-site dynamics with high-resolution data sets[70]. The micro or intra-site analysis techniques aim to understand a wreck or an assemblage of artefacts.

[68] Other European sea Power states French, English and later British, Spanish, Portuguese and Dutch.
[69] Using Orser's definition of modern world archaeology (Orser 1996, 2010, 2016).
[70] Limited in this case to the protected area of a wreck that varies between 100-300m depending on the wreck sites and its dispersion

Based on previous studies carried out on wrecks such as *Invincible* (Quinn et al. 1998), this methodology intends to further extend our interpretation capability by using the latest technology available and adding a more detailed micro-scale level of analysis. The main contribution of this methodological approach is the multiple scales of analysis that are only achieved by a true integration of 4D time-lapse generated by remote sensing techniques, historical sources, and *in situ* observations.

The robust but flexible methodology presented in this chapter (Figure 14), varies in the selection of techniques used for the data collection on the case studies[71] depending on the following factors:

a) Data availability/resolution from previous work
b) Financial/resource availability of projects on the sites (past and current)
c) General site environmental conditions (waves, tides, winds, depth, turbidity, or underwater visibility) that affect data collection during fieldwork in different ways.
d) Weather conditions and underwater visibility, during fieldwork[72], that allowed or restricted the possibility to generate new data, during surveys, and excavations.
e) State of preservation/decay of the wreck (coherent or incoherent structure and artefact distribution)
f) Time-frame that limits this study

Environmental studies are essential for understanding the interaction with the sites. As we are seeking a holistic interpretation this thesis will include both *n-factors*[73] and *c-factors* including the *extracting filters* and *scrambling processes*[74] of each case study (see Chapter II).

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[71] *Hazardous, Invincible* and *Rooswijk*
[72] The weather conditions may varie from the general site conditions from one day to another.
[73] The natural (*n-factors*) and cultural (*c-factors*) (Schiffer 1987:7).
[74] *Extracting filters*, defined as mechanisms that took material away from the wreck, such as the nature of the wrecking process, salvaging, and disintegration of objects (Muckelroy 1978:165-169; Stewart 1999:567). Secondly, *scrambling processes* that begin during the process of wrecking. This included the post-depositional wrecking processes that are constituted of waves, currents, seabed movement, and bioturbation (Muckelroy 1978:169-182; Stewart 1999:567).

It is important to recognise that all three shipwrecks analysed in this thesis are modern historical vessels. As such general historical-archaeological methods are relevant for further archaeological interpretation. According to Orser (2016:23), the three main principles in historical archaeology are: first, to provide information useful for historic preservation and site interpretations. Second, to document the lifeways of past peoples; and thirdly, to study the complex process of modernisation and all the cultural and social change adaptations, and non-adaptations that accompanied it [As Adams explains innovation and social change (Adams 2013a)]. However, social interpretation goes beyond the scope of this thesis of time and word limits constraints.

3.1 Stages

This methodology can be divided into three main stages: desk-based assessments, fieldwork (surveys and excavation) and site monitoring. However, this cyclical research model required data processing during each stage, and in particular, after the production of new data that triggered a further analytical phase.

The DBA allowed for a critical examination of previous work and includes determining the accuracy and resolution of each dataset. This is essential to either include or discards data (grey literature, RAW files from remote sensing techniques, archives, archaeological surveys and excavation record including artefacts), address the gaps in knowledge and target new areas for a survey to aid our site interpretation of each wreck. It is preferable to work with the primary sources to determine data quality or re-process if necessary.

Fieldwork provided the crucial second stage to this methodology as it allowed for new data to be generated on each wreck (to varying degrees) and cross-comparison with previous work/observations. All of the surveys and excavations carried out on *Hazardous*, *Rooswijk* and *Invincible* included remote sensing techniques, (geophysics, photogrammetry, photographic and video recording, as well as traditional-hand drawing with direct survey measurement (DSM), trilateration, direct measurement, or a planning frame). It is important to mention that time efficiency in data collection as well as the quality, and accuracy improved substantially throughout the length of this study. However, several experimental stages were required to guarantee best results.

Site monitoring with direct measurements and remote sensing techniques forms the third stage of this methodology. This stage consists of the analysis of the environmental dynamics and their possible impact on the wreck. Such environmental dynamics can be observed through time series data and result in the identification and selection of critical areas and features. This approach is available to any site, however, not many sites enjoy the detailed high-resolution survey as the ones presented in the case studies of this thesis. Normally data is seldom collected from submerged wreck sites, due to financial or resource availability with large teams to carry out research. This restricts the possibility of having repetitive surveys on the same site on multiple scales.

Data processing is continuously carried out throughout all stages. However, the interpretation of each wreck requires an analytical phase where finally data integration is essential to present a robust model for each wreck's site formation process.

3.2 Sources and materials

This section will outline the sources and materials that were consulted during this research and includes a critical evaluation of these techniques and methods, along with the justification for their use or future potential use.

As stated in the section above, the baseline assessment of each wreck is crucial to understanding and recreating its life story, in a similar way to a doctor evaluating a patient before diagnosis. Revising the historical background, in its use-life and the previous work carried out on the wreck site, it can provide contextual information to understand how the wreck site was created or how previous investigations might have impacted its current state of preservation.

This methodology aims to address the site formation processes from multiple-scales (space and time) and to achieve a broad methodology with a wide range of tools (as presented in Figure 14).

Hazardous, Rooswijk and *Invincible* have all had previous work on site that produced valuable information. These sites have hosted multiple projects that carried out several phases of research, including surveys, excavations, post-excavation analysis and publication. The data produced from previous and current projects have been integrated here into the same spatial units on a t-GIS platform, ArcMap ® 10.5 and Site Recorder 4 ®.

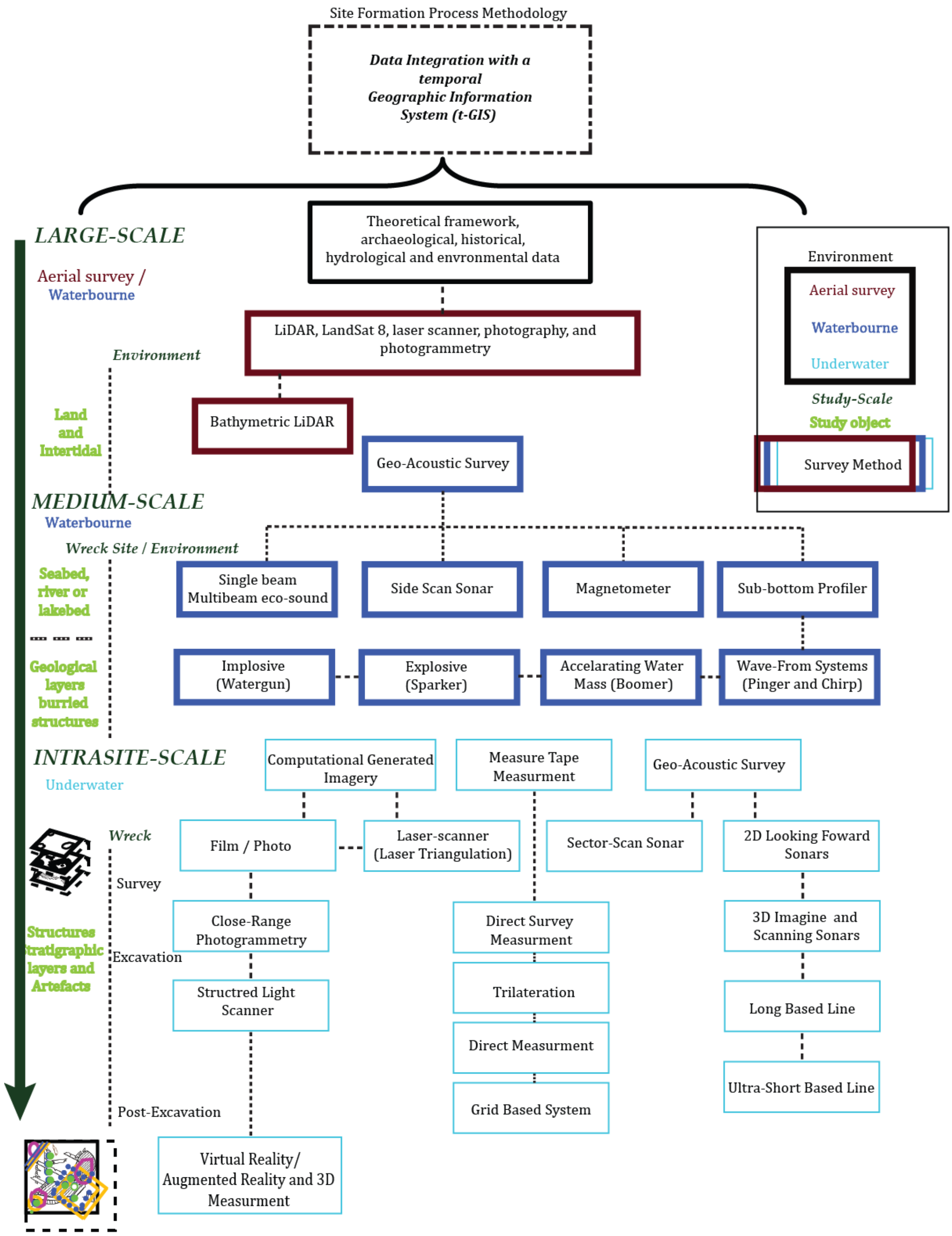

Figure 14. The methodological diagram co-relates techniques with a specific study scale to answer the question of the site formation process. Created by the author.

3.2.1 Archives (charts, maps, and ship logs)

Archival research is essential to build a ship's life story, from its commission, use life and its possible salvage after wrecking and its rediscovery. By looking into the ships' construction, transformation, repairs, cargoes, crew and their personal belongings in the historical documents it is possible to either complete a picture or challenge it with the archaeological record. Ship plans, charts, and ship logs are essential in understanding how the ship was built, where she worked and how she perished.

Some modern ships are better documented than others or the degree to which their archives and published sources are accessible varies. Some primary sources have also been consulted at the National Maritime Museum (NMM)[75], Royal Greenwich Museum (RGM), National Archives (NA), National Trust Collections (NTC), British Library (BL), Biblioteque National de France (BNF) and Museé National de la Marine (MNM). Fortunately, *Invincible* is well documented with an excellent historical recollection by Lavery (1988, 2009). *Hazardous* has also been documented and researched by the Hazardous Project (Owen 1991), while others such as *Rooswijk* have less information available (Chapter 6).

Historical maps and charts are other valuable sources of information to reconstruct the archaeological landscape. However, their quality depends mainly on the sources as they can vary widely in accuracy and precision. It is therefore essential to consider their methods and reasons for creation (Seasholes 1988:93). Archaeologists must evaluate historical maps in the same way that they would any historical document, taking into account what is known about the mapmaker, the map's purpose, and its intended audience (Panich, Schneider, and Byram 2018). Early cartography was a practical and visual tool to demarcate land but also served primarily as a tool with which colonial policy was exacted. In this context, maps were both a guide for exploration and a record of material conquest (Mrozowski 1999). Maps and charts were the results of the ways the world was perceived and experienced and were an

[75] Capitan Bentley's log (PRO Adm 51/471), Lieutenant's Logs (NMM ADM/L/J/ 87), Court martial minutes (PRO Adm 1/5297), NMM POR series (POR/F/11 and POR /D/13), NA PRO series (PRO adm 51/673, PRO adm 106/1191, PRO adm 2/522, PRO adm 1/926, NMM ADM/Y/5 (Ortiz-Vázquez 2013)

analogue for the acquisition, management and reinforcement of knowledge and colonial power. Therefore, maps and charts were both the result of human action and provided some basis for future activities (Dellino-Musgrave 2006:141). Several types of maps, charts and illustrations can be analysed for reconstructing the archaeological landscape. Historical cartographical material includes atlas maps, directory maps, insurance and real estate atlas, utility maps and other specialised maps or plans. Such earlier maps also included illustrations or paintings that required a more artistic license such as bird's eye views[76]. The map of Pierre Charles Canot from 1754, *A Geometrical Plan and West Elevation of His Majesty's Dock-Yard near Portsmouth*, is an example of this (Canot 1754)[77]. Bird's eye view plans can be useful for things such as port and harbour reconstruction (O'Flanagan 2010) or understanding the general spatial distribution of maritime activity. Unfortunately, in the case of *Invincible, Rooswijk* or *Hazardous* none of them includes an accurate survey of the wrecking area. On the other hand, old and modern charts produced by the UKHO or IMRAY can be used to reconstruct sediment migration. To reduce the error while geo-referencing paper charts onto a GIS platform, high-resolution orthophotos covering the coastline were added (CCO 2018). Also, the same tie points referenced to landmarks were used to avoid further distortion. The depth on old charts was plotted in fathoms[78], which needs to be converted into metres. Followed by converting that value into CD[79] or LODN[80] (Portsmouth) to compare with modern charts and MBES surveys (Figure 15).

Large-scale and mesoscale. Historical sources can answer research questions to different scales, depending on the information found in a ship's log. This can go from large and mesoscale descriptions of weather conditions (Wind direction and force and tides), or maritime landscape descriptions (seabed characteristics, navigational hazards, anchorages and landfall views). Contemporary and Modern day charts and maps are also essential to understand the area of the wreckage, and when complemented with direct descriptions they gain even more value. Another Valuable

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76 See chapter VII on *Invincible* where the ship is shown on a plan describing Portsmouth dockyard, shown from a bird's view.
77 *Invincible* is illustrated in the Naval Dockyard in this map.
78 1 fathom = 1.8288m
79 Chart Datum
80 Local Ordnance Survey Newlyn

source of information is the Minutes of Court Martial that contain lengthy explanations of the wrecking process, the environment and distance to the coast.

Intra-site scale. Both ship logs and Minutes of a Court Martial have remarkably detailed descriptions the state of the ship (Seaworthy, repairs, damage and loss), a description of its cargo, and the men on board, everyone's tasks during the wrecking event, etc. (Gibbs 2006; Gibbs and Duncan 2016; Oxley et al. 2016)

All the sources mentioned above are relevant to determining how events developed and probable or certain wrecking causes. The next section will focus on the post-wrecking events when the use of remote-sensing techniques are utilised to survey and monitor the site.

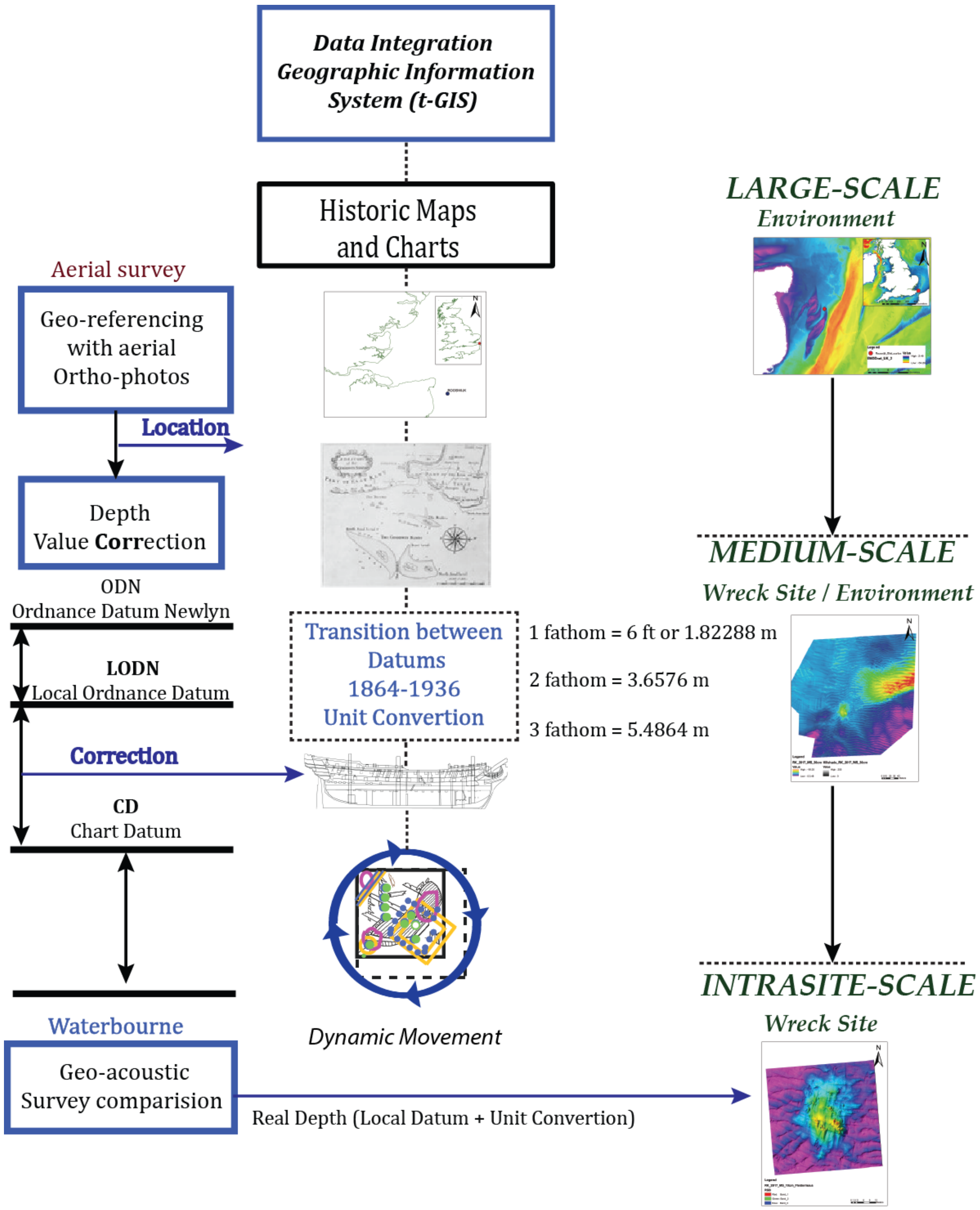

Figure 15. Explanation of depth correction for historic charts depending on the depth datum ODN or CD. The illustration created by the author of this thesis.

3.3. Remote Sensing

This section of the methodology will present the remote sensing techniques that were applied to the case studies within this thesis. However, it also serves to highlight and discuss other technologies that have the potential to record other wreck sites.

The aim here is to present data integration with a critical analysis of the limits and capacity of each technique for better site interpretation at different scales. Therefore, each method discussed in this section will be separated into the macro, meso and intrasite-scale to allow for clarification in the difference of data capture.

3.3.1 Marine Geophysics

3.3.1.1 Multibeam Echo-Sound

Large-scale, Multibeam Echo-Sound (MBES) is an acoustic[81] hydrographic survey tool that is now commonly used in maritime archaeology for its capability to map the seabed with a high degree of accuracy covering extensive areas. The techniques' versatility to cover large areas and to access submerged sites allows studying of extensive submerged palaeo-landscapes (Bynoe 2017; Dix 2000; Gaffney et al. 2007; Garrow and Sturt 2019; Pacheco 2015; Sturt et al. 2016), to surveying specific shipwreck sites (Astley 2016; Astley et al. n.d.; Bull et al. 2005; Dix et al. 2006; Gutowski et al. 2008; PAS 2017; Plets et al. 2009; Quinn, et. al. 1997; Quinn et al. 1998; Quinn, et al. 1997).

Meso-scale, high-resolution MBES systems can also work in the range below 1m between soundings. A MBES is based on a Two-Way Time (TWT) measurement between the transmitting pulses emitted from the transducer to the seabed that bounces back to a transceiver. Necessarily, a Global Navigational Satellite System (GNSS) is used for timing the exact moment the pulse is emitted and when it returns, as well as its position; critical for accurate mapping. Calibration is fundamental to understand the distance between the transmitter and the seabed, a sound velocity profile (SVP) has to be taken at least before every survey area is mapped. Positioning and accuracy will depend on the correct adjustments with vessel configuration, latency, pitch, roll, heave and tidal correction.

This thesis points towards integrating different techniques for further interpretation and characterisation of the seabed. MBES can acquire accurate positional data, with a relatively low-resolution seabed terrain and images.

[81] Active sonars including echo sounders use transducers that are most commonly blocks of piezoelectric materials that expand, contract or change shape when electrical voltages are applied and generate voltage when they vibrate in response to impinging sound waves (Clay and Medwin, 1977; O'Brian 2002:16).

Zhao *et al.,* have successfully integrated MBES and side scan sonar (SSS)[82] data to combine accurate positioning with high-resolution images of the seabed (Zhao et al. 2017). This method was successfully applied to identify and characterise seabed sediment types, but the resolution is insufficient to identify the archaeological material. Quinn *et al.* (2005) have tested SSS and its backscatter trying to identify possible archaeological material. They concluded that it is apparent that many of the materials deployed could not be interpreted based on their backscatter response alone. Therefore, other higher resolution techniques must be used to acquire that level of detail.

MBES can produce a time-series when an area is surveyed on a periodical basis (Bates et al., 2007; Quinn and Boland, 2010; Stieglitz and Waterson, 2013; Brennan et al., 2016). However, as Astley pointed out shipwreck taphonomy requires a great deal of scrutiny of the MBES datasets used to build a time-series (Astley 2016), stating that it is necessary to work with RAW data not only processed values, due to the uncertainty of values, while collecting, processing and displaying data.
Unfortunately, most datasets that were acquired in the past are difficult to have in their RAW format. Nonetheless, some data has been re-processed in a format that can be used to produce a time-series for site formation processes. As each time-series of MBES datasets vary from site to site, specifying the equipment, its frequencies, resolution, software for processing, format, positioning system used and a vertical datum is important (See Table 1, Table 2 and Table 3).

[82] SSS is further discussed in section 3.3.1.3.

Hazardous Marine Geophysics							
Date	**Survey**	**Equipment**	**Frequency/ Resolution**	**Software Process**	**Format / RAW**	**Gridded Resolution/ Positioning**	**Datum**
02/07/2014	WA	R2Sonic 2024	455 kHz	HyPack Navigation and QINsy	HSX /.xyz	.50cm D-GPS	WGS84 30N/ CD
07/10/2013	CCO	Kongsberg EM3002D, EM2040D	200 /400 kHz	Uncertain	.xyz ASCII	1m	OSGB36/ ODN
29/09/2003	WA /ALSF	Reson SeaBat 8125 multibeam	455 kHz	HyPack Navigation and QINsy	.txt	.50cm RTK	WGS-84 / CD
29/09/2002	WA	Reson SeaBat 8125 multibeam	455 kHz	-	.pts	.50cm D-GPS	WGS-84 / CD

Table 1 MBES datasets for *Hazardous*

Rooswijk Marine Geophysics							
Date	**Survey**	**Equipment**	**Frequency / Resolution**	**Software Process**	**Format / RAW**	**Gridded Resolution / Positioning**	**Datum**
2018	MSDS Marine Ltd	R2 Sonic 2024	450 and 700 khz	HyPack Navigation and QINsy	.xyz	RTK / .20cm	WGS84/OD Dover
2017	MSDS Marine Ltd	R2 Sonic 2024	450 and 700 khz	HyPack Navigation and QINsy	.xyz	RTK / .20cm	WGS84/OD Dover
2016	MSDS Marine Ltd	R2 Sonic 2024	450 and 700 khz	HyPack Navigation and QINsy	.xyz	RTK / .20cm	WGS84/OD Dover
2015	MSDS Marine Ltd	R2 Sonic 2024	450 and 700 khz	HyPack Navigation and QINsy	.xyz	RTK / .20cm	WGS84/OD Dover
09/10/ 2010	CCO	Reson 7125 Dual Head	400 kHz	HyPack Navigation and QINsy	.xyz ASCII	1m	OSGB36/OD N
21/01/ 2011	CCO	SEA Swath Plus	468 kHz	HyPack Navigation and QINsy	.xyz ASCII	1m	OSGB36/OD N

Table 2 MBES datasets for *Rooswijk*

Invincible Marine Geophysics							
Date	**Survey**	**Equipment**	**Frequency / Resolution**	**Software Process**	**Format**	**Gridded Resolution/ Positioning**	**Datum**
01/12/ 2016	MBES/ UoS	Reson SeaBat 8125 multibeam (Reson Inc 2002, 2017)	455 kHz	CARIS HIPS® version 8.0.0	(.pds) or (.xtf) into xyz in a Lat., Long. and depth	.20cm/RTK	WGS843 0N/CD

24/11/2015	MBES/UoS	Reson SeaBat 8125 multibeam (Reson Inc 2002, 2017)	455 kHz	CARIS HIPS® version 8.0.0	(.pds) or (.xtf) into xyz in a Lat., Long. and depth	.20cm/RTK	WGS843 0N/CD
02/07/2014	MBES/WA	R2Sonic 2024 (R2 Sonic 2016)	400	HyPack Navigation and QINsy	.xyz	.25cm/ D-GPS	WGS84 30N/ ODN
07/10/2013	MBES/CCO	Kongsberg EM3002D, EM2040D	200 /400 kHz	Uncertain	.xyz ASCII	1m / D-GPS	OSGB36 / ODN
29/09/2003	MBES/WA	Reson SeaBat 8125	455 kHz	HyPack Navigation and QINsy	.pts/.xyz	.50cm / D-GPS	RTK WGS84/ CD
2002	MBES/ADU	Reson SeaBat 8125	Uncertain	Uncertain	.pts	.50cm /-	WGS84 30N /-

Table 3 MBES datasets for *Invincible*.

3.3.1.2 Positioning, Accuracy and Uncertainty

To record the position of any marine geophysical survey a Global Navigational Satellite System (GNSS) is required to provide our X and Y coordinates, and Z values (when using RTK Tides), as well as a time stamp (MCA 2013:14). Inertially-aided real-time kinematic (IARTK) systems blend GNSS data with angular rate and acceleration data from an inertial motion unit (IMU) and heading from the GPS Azimuth Measurement System (GAMS) to produce a robust and accurate full six degrees of freedom position and orientation solution (Applanix 2017). Post-processing software, POSPac Mobile Mapping Suite™, can correct the centre point of accuracy when the GNSS signal is temporarily lost[83]. POSPac positioning is vital for every survey. However, it is particularly significant when the surveyed area is further away from the coast. Specifically on the *Rooswijk* that is 13km (8 miles) from the coastline, and *Invincible* 5km (3.8 miles) and losing RTK signal from the base station network for a few second requires this level of calibration.

The inertial motion unit (IMU) records all rotational offsets that the survey vessel has during the survey, that control the pitch (∘), roll (∘), heave (∘) and yaw (∘). Before any

[83] On *Rooswijk* Positioning and motion for the MBES was controlled using an Applanix POS MV WaveMaster with real time RTK corrections. The Applanix system with RTK corrections produces positional accuracy of >0.1m, roll and pitch to 0.02°, heading to 0.03° and heave to 2cm or 2%. Where required, the position data was post-processed in POSPac to improve absolute accuracy (PAS 2017).

survey, a patch test must take place to correct values in Latency, Pitch, Roll and Yaw that varies from each survey vessel. Additionally, a Vessel Configuration File, (HIPS Vessel File (HVF)), that shows the offset between the GNSS, IMU and Sensor is required. Sound velocity measurements are required, and applied to the MBES data, to calibrate variations in the speed of sound through the water column, with an SVP[84](PAS 2017).

Finally, tidal corrections are also another source of uncertainty on the Z values of the MBES. Tidal correction can be done with RTK or to the nearest tide gauge. However, the further the gauge is from the survey site and the more extensive the tidal range at the site, the larger the error will be introduced through the tidal correction from .1 m >[85] to <[86] .3 m (Astley 2016).

There are differences in values on X, Y, and Z accuracy using D-GPS systems and RTK. Therefore, for best practice to minimise positional and tidal correction errors, RTK is highly recommended. To avoid further accumulative error, it is important to use the same Datum between datasets within the same time-series. Chart Datum (CH), Ordnance Datum (OD) or Vertical Offshore Reference Frame (VORF).

There are minor differences between processing MBES data with CARIS HIPS and SIPS ® and HYPACK® (See Figure 16 and Figure 17). However, they both use the same variables and produce an ASCII file (.txt, .pts, .xyz, or GeoTIFF). By manually cleaning the data, some differences can be visible with the point cloud.

The cleaned ASCII file can be processed and displayed with Cloud Compare®, or Fleidermaus®.

Another common way of displaying MBES is gridding the data and producing a DEM. Astley recommends ensuring all surveys are gridded to the same grid. This should not be at a resolution finer than the coarsest survey resolution. Through gridding, data can be created (interpolation) and lost (if too coarse resolution used) (Astley 2016:39–42).

Once the data is cleaned, the survey lines can be imported into Fledermaus® and Cloud Compare ®, where the data is visualised, and effects such as shading applied (PSV plugin, hillshade, colour schemes) to highlight potential anthropogenic features.

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84 On *Rooswijk* a Valeport Mini Sound Velocity Sensor (SVS) and at intervals through the water column with a Valeport Sound Velocity Profiler (SVP).

85 Grater than >

86 Less than <

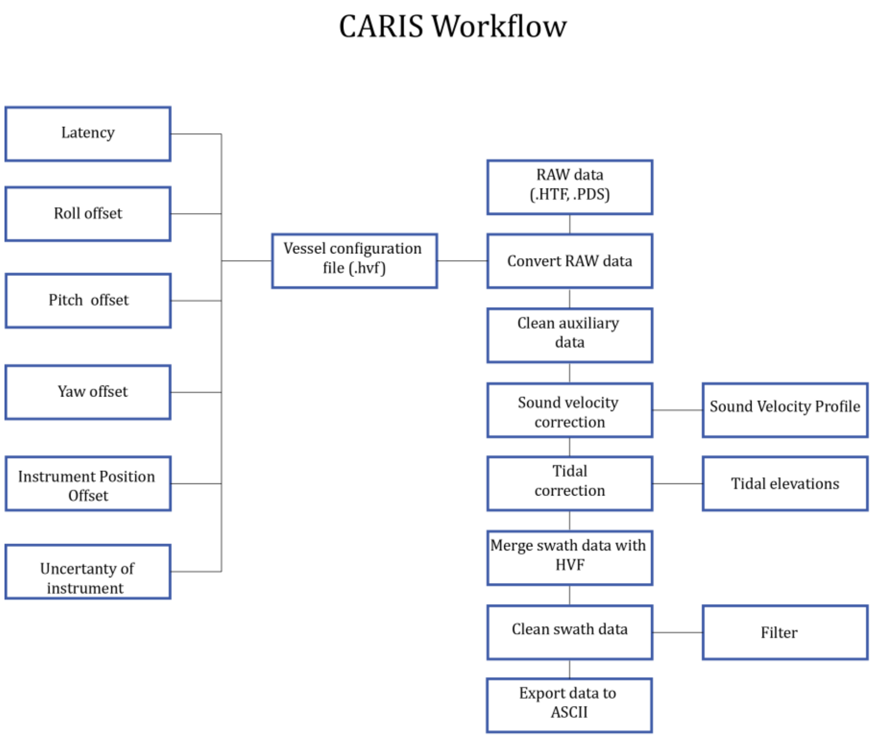

Figure 16. CARIS HIPS ™ work flowchart required to process raw MBES data into a clean xyz file (After Astley 2016:28).

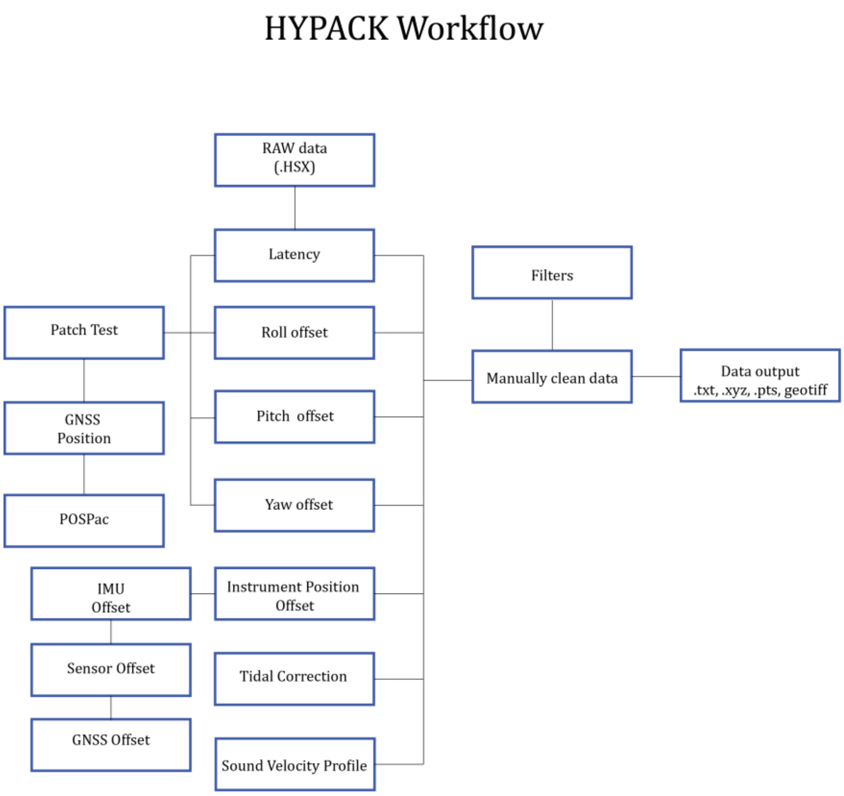

Figure 17. Hypack ® MBES processing workflow based on (Burnett 2013; Shaw 2015).

3.3.1.3 Side Scan Sonar

Large and mesoscale. Side scan sonar (SSS) is perhaps the most popular acoustic marine geophysical tool. It has proven to be an invaluable method for locating shipwrecks, even at great depth. It can produce high-resolution imaging, which shows the difference in height by casting shadows and as well for classifying seabed sediment (Bates et al. 2011; Quinn et al. 2005).

SSS can be used to monitor wrecks and display changes in structure coherence. However, for this study, the resolution is inadequate as well as its analytical capabilities to monitor sediment migration. The SSS data from WA (2014)[87] used on *Hazardous* proved to be of great aid to identify large uncovered features, such as timbers, and a cannonball mound associated with the ship and linked to the wrecking process (Table 4). However, there are great distortions between each survey line when the GeoTIFF mosaic is created (Figure 18). Furthermore, the output produced is a flat image, meaning that there are no associated depth values as a raster[88] file from the MBES data (ESRI 2018d), making it impossible to track sediment migration on a quantitative basis. However, sediment transportation can be observed qualitatively through morphological changes (Figure 19).

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[87] Figure 59.

[88] In its simplest form, a raster consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information (ESRI 2018)

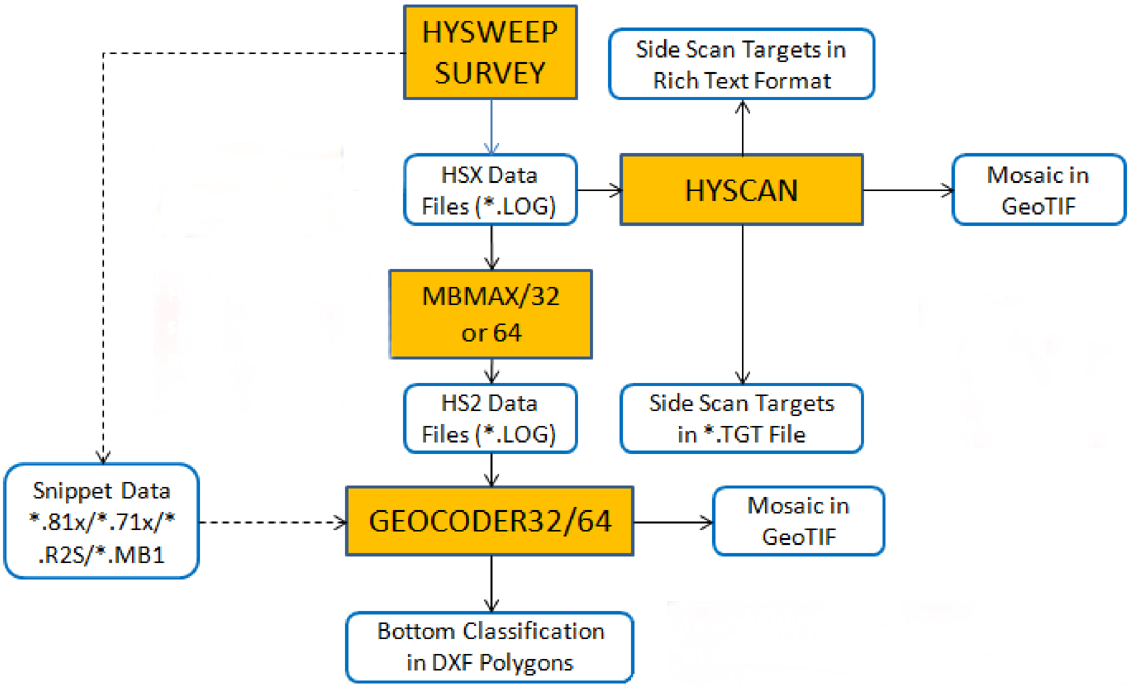

Figure 18. Hypack SSS processing workflow (Burnett 2013).

Invincible/Hazardous						
Date	**Survey**	**Equipment**	**Frequency/ Resolution**	**Software Process**	**Format**	**Gridded Resolution/ Positioning**
02/07/2014	WA	Klein 3900	20m spacing / 900khz	SonarPro / Coda GeoSurvey	(.xtf) into xyz in a Lat., Long. and depth	D-GPS

Table 4. SSS survey specifications for *Hazardous* and *Invincible* from WA (2014).

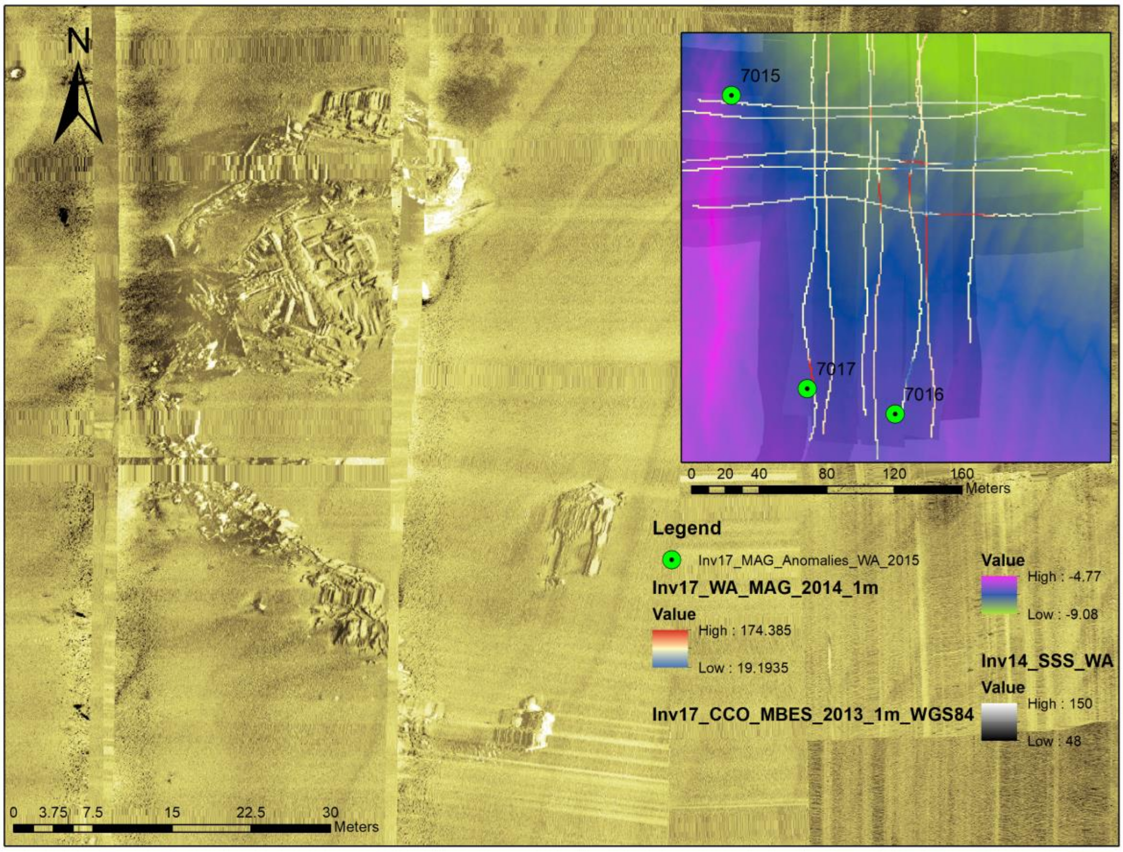

Figure 19. SSS from WA 2014 and MAG 2014 survey on the top right corner showing three anomalies 7015, 7016 and 7017.

3.3.1.4 Magnetometer

Large and mesoscale. A magnetometer is also a popular survey tool that locates ferrous material by measuring changes in the earth's magnetic field[89]. This equipment measures the variations in the earth's magnetic field caused by interacting ferromagnetic material. The use of magnetometers is extremely popular to locate shipwrecks and associated ferrous material, which could be buried by sediments or coral reefs (Batchvarov 2016; Bates et al. 2011; Quinn et al. 2007). This is an effective interpretation technique to cover extensive areas in a relatively short time. However, there are limitations of using a magnetometer, especially when trying to locate shipwrecks that have very low concentrations of ferromagnetic material. Furthermore, the line spacing is critical in creating the appropriate reading over a shipwreck (Babits and Van Tilburg 2013:355–75).

[89] Magnetic methods measures the earth's total magnetic field at each measurement location (EPA 2018).

On *Invincible* and *Hazardous* the magnetometer surveys were carried out to locate guns associated with the wrecking event (Table 5). Therefore, it is useful to understand part of the site formation process, by locating magnetic anomalies and possibly revealing new elements. However, for monitoring site dynamics on shipwrecks and measuring changes, this technique is less effective. Thus, this is the importance of integrating it with other geophysical and archaeological data (Figure 19. SSS from WA 2014 and MAG 2014 survey on the top right corner showing three anomalies 7015, 7016 and 7017.).

Invincible/Hazardous						
Date	**Survey**	**Equipment**	**Frequency/ Resolution**	**Software Process**	**Format**	**Positioning**
02/07/2014	WA	Geometrics G-882 Caesium Vapour	10 Hz	Geometrics MagLog Lite	.GEOMAG, converted to .txt	D-GPS

Table 5. Magnetometer survey parameters for Invincible and Hazardous done in 2014 from WA (WA 2015).

3.3.1.5 Sub-Bottom Profilers

Large and mesoscale. Sub-bottom profilers (SBP) are seismic[90] techniques with immense potential for future archaeological research on shipwrecks. This technique can go beyond the seabed, and possibly determine the full extent of archaeological sites with a non-invasive technique. This is a refined technique to dissect an archaeological site, on target areas instead of covering extensive ground to locate shipwrecks. However, it requires having *in situ* archaeological ground proving for accurate interpretations, as demonstrated by on the *Mary Rose* (Quinn et al. 1997) *Yarmouth Roads* wreck (Plets et al. 2008) and *Invincible* (Quinn et al. 1998). Having previous knowledge of the extent of the remains or an accurate location of where they are buried allows having targeted surveys, adequate line spacing and a dense data set. Otherwise, it is difficult to detect "small" features (such as wrecks) with low-frequency acoustic surveys that are made for detecting geological features at a much larger scale.

Improved systems of SBP have managed to successfully integrate with MBES and SSS and produce a pseudo-3D volume, such as on the *Yarmouth Roads* wreck (Plets et al.

[90] Any mechanical vibration is initiated by a source and travels to the location where the vibration is noted. These vibrations are seismic waves. The vibration is merely a change in the stress state due to a disturbance.

2008) and a real 3D volume, as on the *Grace Dieu* (Plets et al. 2009). These studies provided new information on the possible extent of the buried structure of the wrecks. However, the resolution does not display the structural complexity of a shipwreck.

The pioneering effort of Quinn *et al.* (1998) of using a 3D chirp system on *Invincible* opened a new realm of possibilities to monitor submerged underwater cultural heritage. However, this only shows a single cross-section of an area still requires an *in situ* confirmation with an archaeological excavation. These techniques have been applied in other parts of the world such as, Israel (Akko 4, *Ashkelon* shipwreck), Denmark (*Lundeborg* Wreck 1), in Germany (*Haithabu* 4) (Grøn et al. 2015; Vandiver 2002) and in the Dutch Waddenzee (*Scheurrak*) (Romijn et al. 2004:3).

The new system re-configurated 3D chirp system made by Kongsberg (2018), with RTK positioning, has the possibility to genuinely reveal the full extent of the site, showing a real 3D volume with the *Holigost* (Dix et al. *Forthcoming*). However, we must also consider that the resolution determined by the extent of the survey, the remaining structure (or absence), and site conditions that limit the returning pulse. Another example is the SBP survey that will be carried on the *London* in 2019. This survey represents a new set of challenges with a seabed of thick clay sediment and a high-energy environment that impact on the sea state during the survey[91]. The extensive remaining structure has heavily concreted areas that will limit acoustic penetration. Mapping the bedrock underneath the remaining wreck structure will be extremely difficult even using state of the art equipment.
Hence, the importance of archaeological excavations that will provide the intra-site scale level of interpretation that will give further interpretation possibilities (Cotswold Archaeology *forthcoming*).

3.3.2 Underwater Acoustic Positioning Systems

3.3.2.1 Ultra-Short Based Line

Intra-site scale. The Ultra Short Baseline (USBL) is a portable system that has a vessel-mounted acoustic transmitter (transceiver) and several receivers (transponders). The transceiver interrogates subsea transponders attached to targets being tracked (ROVs, divers, or a towfish), captures the return signal and calculates the range, bearing and

[91] The wreck is located in the Thames river delta with a dynamic tidal range.

declination to determine the relative x, y, z position from the vessel (SONARDYNE 2012:1). The positioning of each transponder is then georeferenced by integrating a GNSS signal allowing tracking and positioning of multiple subsea targets simultaneously. The USBL was fundamental during the Rooswijk excavation. This system enabled the project to position the excavation grid, the artefacts, track divers, wet bell, and lifting crane. It was an essential tool regarding speed for recording and having an underwater reference to position the vessel for deploying the wet bell and lifting crane for operations on site. Diver's safety was also improved by adding the USBL tracking system, enabling the diving supervisor to monitor their positions at all times (Figure 20. Diver deploying a mobile transponder to record an archaeological artefact position. The image is a frame by the author of this thesis taken from underwater footage filmed by Mike Pitts. The image is courtesy of RC). Regarding the archaeological recording of artefacts, features and general site description, this was very important, especially with limited visibility and strong currents that restrict divers' time.

Calibration to guarantee the best accuracy was possible by having a minimum of two to four fixed transponders on the excavation grid and a four-point mooring vessel on site, during neap tides. This allowed to take multiple fixes throughout the day even when diving operations were not taking place, although this was only possible during slack tides. The SCOUT SONARDYNE system (SONARDYNE 2012) follows the strict International Marine Contractor Association (IMCA) guidelines, taking into account the accuracy of the GNSS surface positioning and the capability of performance and accuracy required in offshore operations (IMCA 2016).

During the 2017 fieldwork season of *Rooswijk* the USBL positioning, and tracking was plotted with Site Recorder 4® (3H 2006), and then exported into ESRI ArcMap 10.5® (Figure 20).

Figure 20. Diver deploying a mobile transponder to record an archaeological artefact position. The image is a frame by the author of this thesis taken from underwater footage filmed by Mike Pitts. The image is courtesy of RC

3.3.2.2 Long baseline

Intra-site scale. Long baseline (LBL) techniques are employed to provide an accurate positioning system at depth. It is typically employed for navigation or underwater surveys by ROV or AUV systems and not by divers. The LBL system works by using several calibration stations in an array known as a hub-to-hub set-up. Each hub has a pressure/depth sensor with a subsea gyro. These hubs or transducers are then in communication with several instrumented transponders and they are used to calibrate each station (IMCA 2012:11). The main difference between LBL and USBL is the accuracy, as its calibration methods with multiple transducers and transponders create a network that requires re-calibration every time it is redeployed. The LBL systems' area of operation is limited to the location of the subsea reference beacons and the seabed topography. This system is used in deep-sea operations for surveys but due to its complicated set-up and operational costs, it has not been used for archaeological surveys yet.

3.3.3. Multi-Image Photogrammetry

Photogrammetry is a survey technique of making reliable measurements by using photographs or digital photo imagery to locate features on a surface. The result produces the coordinate (x, y, and z) position of a particular point, creating a planimetric feature, or graphic representation of the terrain on a Cartesian plane (Schenk 2005:4; WYTOD 2013:3).

Macro and Meso-Scale.

The history of photogrammetry goes back to the beginning of photography and aerial surveys taken from air balloons in the mid-19th century. However, the first technological leap came with the invention of stereo-photogrammetry by Pulfrich in 1901, pairing two images with considerable overlap, shortly followed by the construction of the first stereoplotter by Orel in 1908 (Schenk 2005:8). Photogrammetry was a widely used survey method for land reconnaissance and mapping during the First and Second World Wars. Analytical photogrammetry came into play with the availability of computers in the 1950s and early 1960s. However, it was not until the early 1990s that digital photogrammetry emerged, using digital images instead of traditional analogue aerial photographs and algorithms to calculate image pairing as well as terrain plotting. Recently multi-image photogrammetry (MIP) has taken a step even further, by reaching out into other disciplines and extending its capability with high-resolution imagery. It is now possible to carry out photogrammetry from space with satellite images (Ryan et al. 2009; Tucker, Grant, and Dykstra 2004), large terrestrial surveys with UAV's[92] (Flener et al. 2013; Mandlburger et al. 2015; Nikolakopoulos et al. 2017; Rinaudo et al. 2012; Suziedelyte Visockiene et al. 2016) and Deep-sea AUV's[93] or ROV's[94] mapping (Drap, Seinturier, et al. 2015; National Geographic 2017; University of Southampton 2017). This technique has become a reliable, cost-effective survey and analytical tool, for research, industry and commercial purposes. For example, in marine biology, this has resulted in the capability of monitoring volume, species diversity, growth, condition, and even health of coral reefs (Raoult et al. 2016; Valadez-Rocha and Ortiz-Lozano 2013).

Maritime archaeology started using photogrammetry and videogrammetry[95] as a recording technique in its beginnings as a scientific discipline. During the excavation of the *Yassiada* 2, George Bass created an analogue system of stereo-photogrammetric recording of the shipwreck (Bass and van Doorninck 1982). In underwater surveying techniques, maritime archaeology has pushed the barriers of the capabilities of analytical photogrammetry, by surveying some wrecks in a wide variety of environmental conditions. However, there is still room for improvement specifically in using photogrammetry as a monitoring tool to understand site formation process and environmental dynamics (Drap 2012; Drap, Merad, et al. 2015; Historic England 2017; Jones 2016; McCarthy et al. 2019; McCarthy and Benjamin 2014; PAS 2015; Radic Rossi

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[92] UAV: Unmanned Autonomous Vehicle commonly known as drones
[93] AUV: Autonomous Underwater vehicle
[94] ROV Remote Operated Vehicle

[95] Videogrammetry is also used in other disciplines to monitor dynamic of gas fluids (Anweiler 2017) or the applications in biomechanics, sport, animation, and virtual reality generation and control (Gruen 1997). Similarly, with a motion from the structure (Raoult et al. 2016; Shervais and Dietrich 2016), it is possible to extract frames from the video to obtain stills, with VLC Media Player®, Adobe Media Encoder ®, Adobe Premiere Pro ® or DaVinci Resolve 16®.

et al. 2019; Semaan and Saeed Salama 2019; Shervais and Dietrich 2016; Yamafune, Torres, and Castro 2016).

Intra-site scale. The importance of this technique in maritime archaeology relies on its versatility and the capability to integrate photogrammetric data with other survey data. It has become a standard recording method, but also and more importantly an analytical tool, and even as public engagement display. The flexibility of using different platforms to acquire the photographs, allows archaeologist to record a wide range of objects depending on the study-scale, from large landscape areas to small artefacts (Galeazzi 2016; Historic England 2017; Sulas and Madella 2012).

The accuracy of photogrammetry has been widely demonstrated (Flener et al. 2013; Historic England 2017; USGS National UAS Project Office 2017) on terrestrial surveys and underwater (Jones 2016; Radic Rossi et al. 2019; Yamafune 2016; Yamafune et al. 2016). It will depend on the quality of the photographs used, the site conditions and mainly underwater visibility. Therefore, it is essential to specify the recording methods used on *Invincible*, *Hazardous* and *Rooswijk*, their differences depending on site conditions, equipment availability and final objective.

3.3.3.1 Data Collection Challenges

Underwater photography has to take into account water optics, which changes depending on the location of the water body, depth and the changes during day/night, cloud cover, spring or neap tides as well as seasonal cycles (Biegański and Kasiński 2012). The two main factors that affect underwater photography are light absorption (Figure 21) and light scattering. Even though determining light absorption on a specific site is a complicated matter, in general terms, there is a gradual loss of colours with depth increment.

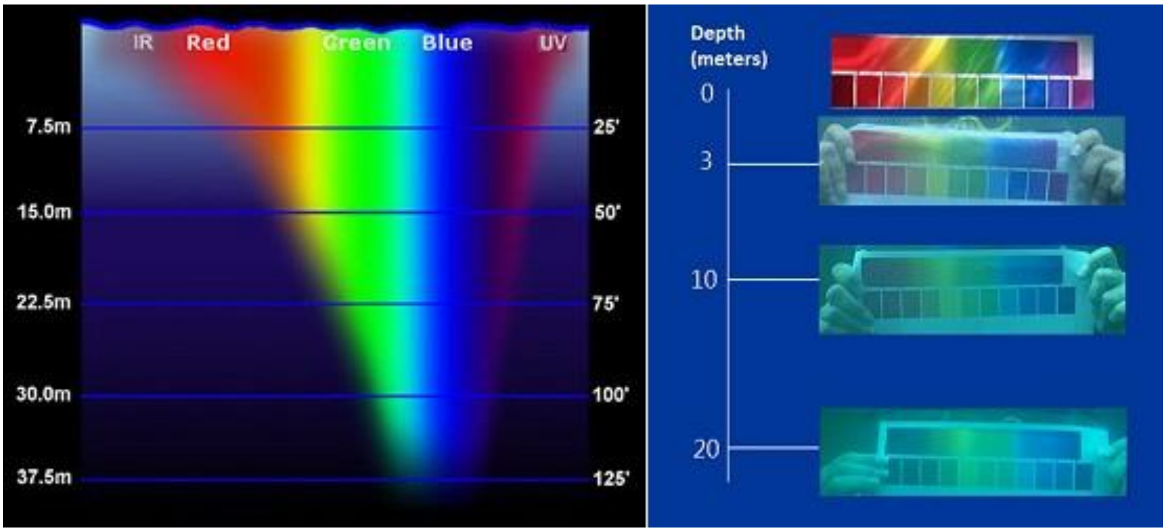

Figure 21. Underwater light absorption. Image from (Chen and Pinel 2017)**.**

The importance of appropriate timing an underwater photography survey is essential to guarantee the best results. Underwater visibility is a crucial factor in obtaining high-definition photographs, and the quality will heavily depend on the camera operator (Jones 2016:93; McCarthy and Benjamin 2014:99–100; PAS & Artas Media 2016; PAS 2018a; PAS and Artas Media 2018; Pascoe 2015:7; Yamafune 2016:709). Tides, currents, weather, storminess, winds and swell affect visibility, especially within shallow water submerged shipwrecks. Predicting good visibility is difficult, but being on site on a daily basis allows selecting the best conditions to carry out the survey[96].

Underwater visibility measurement is still widely debated to be objectively measured, by observational methods with Secchi disk transparency (Zsd)[97] (Kulshreshtha and Shanmugam 2015; Lee et al. 2015), semi-quantitative methods based on optical properties (Simon and Shanmugam 2016) and measuring with remote sensing techniques (Sundarabalan, Shanmugam, and Manjusha 2013). However, for this thesis visibility range is measured on a diver based observation and photograph coverage:

- Extremely poor < 200 mm
- Poor < 1 m

[96] The major challenges of the survey will depend on site dynamics and weather conditions. It has been observed that severe weather is a major factor for underwater visibility, especially in shallow wreck sites. During the summer months, the weather is better, and this has a direct impact on underwater visibility. This is purely observational by visiting the site and comparing different sites.
[97] Secchi disk, a black-and-white disk with a diameter generally about 30 cm, is the oldest “optical instrument” used to measure transparency of ocean and lake waters (Lee et.al 2015:139)

- Fair > 1 m < 3 m
- Good > 3 m < 5 m
- Extremely good > 5 m

In high-energy environments, such as on *Hazardous, Invincible* and *Rooswijk,* it is crucial to do the survey as close as possible to slack water, this will allow the diver to keep a systematic survey following a grid as well as allowing less movement of loose seaweed or other flora on the wreck that can cause issues with overlapping images. In the case of extensive surveys, where a large area is covered by sand, it is essential to have some structure to allow the software to recognise a pattern from one image to the next. For pre-disturbance surveys, in sand patches, the use of markers or scale bars is an essential aid to address these difficulties. Photographs captured for photogrammetric surveys require correction. There are two types of corrections for underwater photography, a physical correction and a software correction that is applied during data collection and in the post-processing (Figure 22).

Higher ISO settings are required in darker conditions, however increasing the ISO sensitivity will lead to adjusting the *f*-stop (aperture) determining a depth of field on the image. The correct settings on the camera will determine whether the picture is sharp, or if it has noise (grain). Some of the features can be enhanced during the post-processing, providing better detail. For this purpose, it is recommended to take pictures in RAW format, and later converted to .jpg, .tiff or .png for further processing (Nikon 2018c).

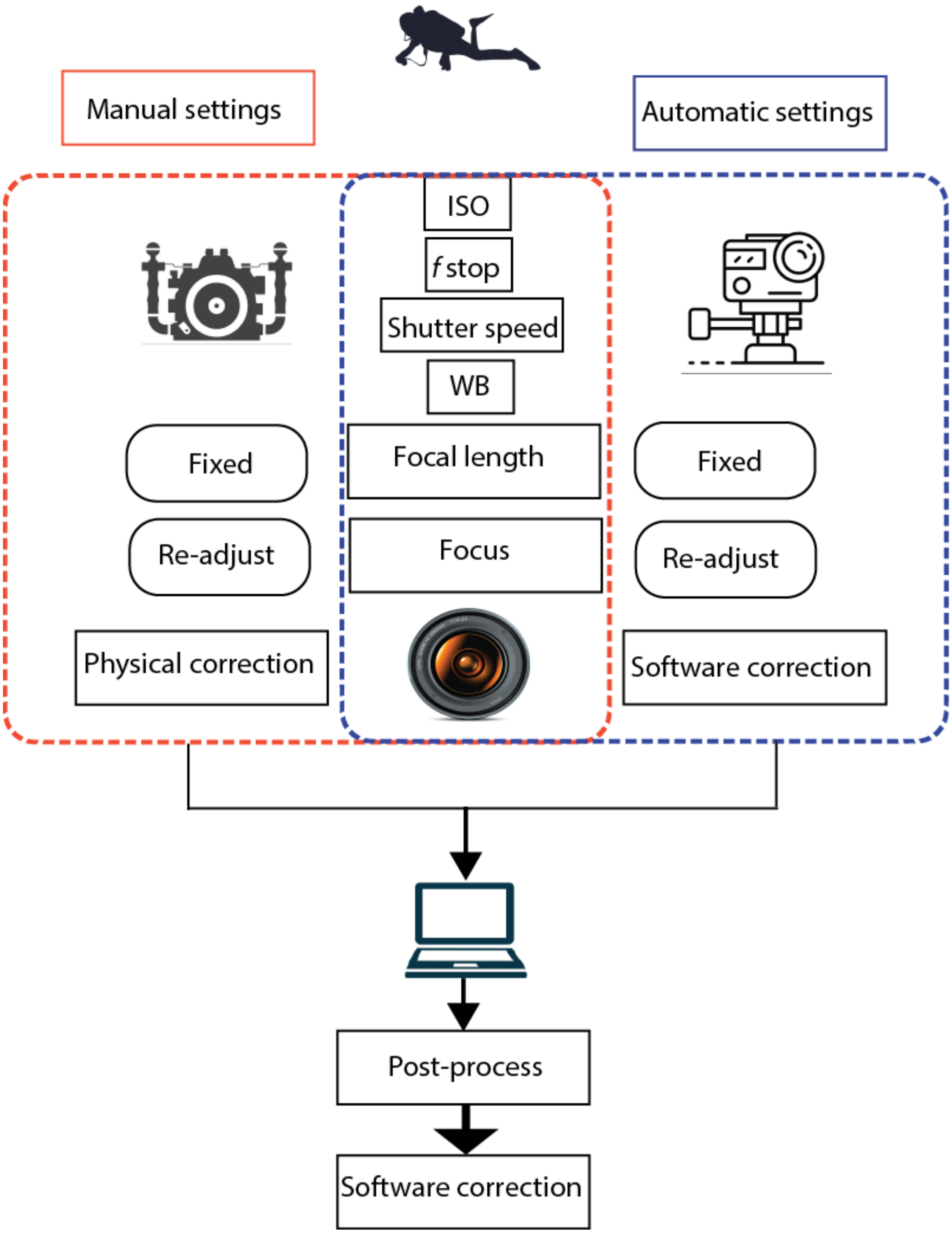

Figure 22. Photograph settings with physical and software correction. Illustration made by the author

As light absorption is a significant factor in losing the original colour, with depth (Figure 21), using an artificial light source or strobes (flash or flood lights), allows counteracting this phenomenon. However, this brings another problem with light scattering depending on the total suspended matter in the water column, which causes backscatter on each picture. Mineral and organic detritus will absorb yellow light and scatter light efficiently. Phytoplankton[98] and zooplankton will influence the optical properties of the water column (bio-optical properties) by absorbing the light with

[98] Phytoplankton, the micro- scopic organisms in the surface ocean, are responsible for half of the photosynthesis on our planet (Dierssen and Randolph 2013:441).

spectral selectivity and creating backscatter[99]. Another major factor is the distortion caused by light travelling through water, captured with a camera sensor passing through the lenses, and the underwater housing (Schechner and Karpel 2005). To counteract the distortion effects it is essential to choose the correct equipment, and/or calibrate for better results. Yamafune *et al.* point out, that during a survey, the hard shadows position from image to image, as well as the stability of colours must be controlled (Yamafune et al. 2016).

3.3.3.2 Data sets on case studies

There are two main data sets collected on the site formation process study for *Hazardous, Rooswijk,* and *Invincible.* First, the photographs collected from underwater surveys of the submerged wrecks and some artefacts *in situ*. Secondly, the post-excavation recording in controlled lab conditions for artefact recording, also used for an ultra-high resolution to interpret site formation process (Table 6 and Table 7).

Understanding changes onsite required having comparable data sets with similar point density, accuracy and geo-referencing. Therefore, data collection was as consistent as possible to guarantee the best resolution. However, each site presents a different environment, with a wide range of challenges. This led to standardising a methodological approach designed to survey, monitor, and to understand site formation processes.

The photogrammetry workflow diagram is divided into four main groups to explain the workflow: data sets, processes, software and file format (Figure 23). The primary data set used in photogrammetry are photographs, but they can also be captured as individual frames (stills), in time-lapse or several frames extracted from video footage. The decision of taking photographs as stills, a time-lapse or video has a direct effect on image quality, also depending on equipment, time constraints, overlap, environmental conditions and most importantly visibility (Table 6).

[99] Ocean color remote sensing provides the long-term, continuous time series of phytoplankton biomass and productivity data necessary for global carbon cycle and climate research, but the uses of ocean color data are increasingly diverse from military to environmental monitoring applications (Dierssen and Randolph 2013:442).

Site	Stills Nikon D800 ®/Nikon D610®	Video Nikon D800 ®/Nikon D610®	Time-laps GoPro Hero4 Black ®	Time-laps GoPro Hero5 Black ®	Time-laps GoPro Hero6 Black®
Invincible	✓	✓	✓	×	✓
Hazardous	✓	×	✓	×	✓
Rooswijk	×	✓	✓	✓	×

Table 6. Underwater survey equipment and technique used on Invincible, Rooswijk and Hazardous.

***Rooswijk* 1740 Project**					
Artefact	ID number	Artefact	ID number	Artefact	ID number
Concretion (12 Satges)	RK17 F0001	Rijder	RK17 A00689	Shoe (Heel)	RK17 A00058
Concretion Chest	RK17 F0002	Pillar Dollar	RK17 A00104*	Clay Pipe	RK17 A0170
Piece of Eight	RK17 A0624	Pewter Tankard	RK17 A0033*	Pulley Block	RK17 A0024
Piece of Eight	RK17 A0112	Jug (Neck)	RK17 A0029	Spoon	RK17 A00133*
Ducaton	RK17 A00687	Pewter Cup	RK17 A00742	Tool Handle	RK17 A00089
Ducaton	RK17 A00961	Candle Stick	RK17 A00743	Copper Tube	RK17 A0032
Onion Bottle	RK17 A00019	Pewter Inkstand	RK18 A00216	Copper Breech Block	RK17 A00146

Table 7. Inventory of 3D Models done with SLS on MSDSMarine Sketchfab (MSDS Marine Ltd and RCE 2017). With kind permission of RCE (https://sketchfab.com/msdsmarine). Full video animation is available at (https://vimeo.com/257165394), generated by the author on 3

The *Hazardous* Project					
Artefact	ID number	Artefact	ID number	Artefact	ID number
Rammer Head	HZ_A002-17	-	-	-	-
Gunners Mop (sponge)	HZ_A003-17	-	-	-	-

Table 8. The Hazardous Project catalogue of photogrammetry models

The *Invincible* Project					
Artefact	ID number	Artefact	ID number	Artefact	ID number
Spool of Tampions	INV17_A00377	Double Pulley Block	INV17_A00409	-	-
Single Pulley Block	INV17_A00379	Fiddle Block	INV17_A00535	-	-

Table 9. The Invincible Project catalogue of photogrammetry models

The use of a time-lapse mode to capture photographs guarantees better overlap from image to image, but also it makes it easier for the camera operator to swim around the site, without having to use a trigger. A time-lapse will have a direct impact on quality, as it is impossible to control and change the cameras' settings manually during each cycle. All the adjustments are done automatically by the camera and software.

The photos are post-processed, colour corrected for better results on the final model as well as converted to a format that Agisoft Metashape Pro ® can work with (Figure 23). Colour correction can be done in RawTherappe ® or Adobe Lightroom ®[100]. The preferred method was to convert from RAW format to 16bit-PNG files and then import them into Agisoft Metashape Pro ®. This allowed maintaining photo quality that provides the best results (Jones 2016:25), with more tie-points and higher density point clouds. Data file storage needs to be taken into account for the archival purpose, as multiple years of data are going to be stored for several wrecks. Also, this allows re-processing previously captured data with newly available software in the future, or with the updated that have considerably improved Agisoft Metashape Pro ®.

Format	Size	Format	Size
.NEF (RAW)[101]	73mb	.JPG-8bit	11.3mb
.PNG-16 bit	207mb	.TIFF-16bit	207mb
.PNG-8 bit	103mb	.TIFF-8bit	103mb

Table 10. File size conversion in Raw Therapee ®

[100] The author of this thesis has observed that Adobe Lightroom ® is better in colour correcting and improving the image quality and sharpness than Raw Therapee ®. Therefore the final product has better texture on the 3D models and the orthophoto presents more accurate colours.

[101] Converted with Raw Therapee ® or Adobe Lightroom ®, from a .NEF (RAW) Nikon file.

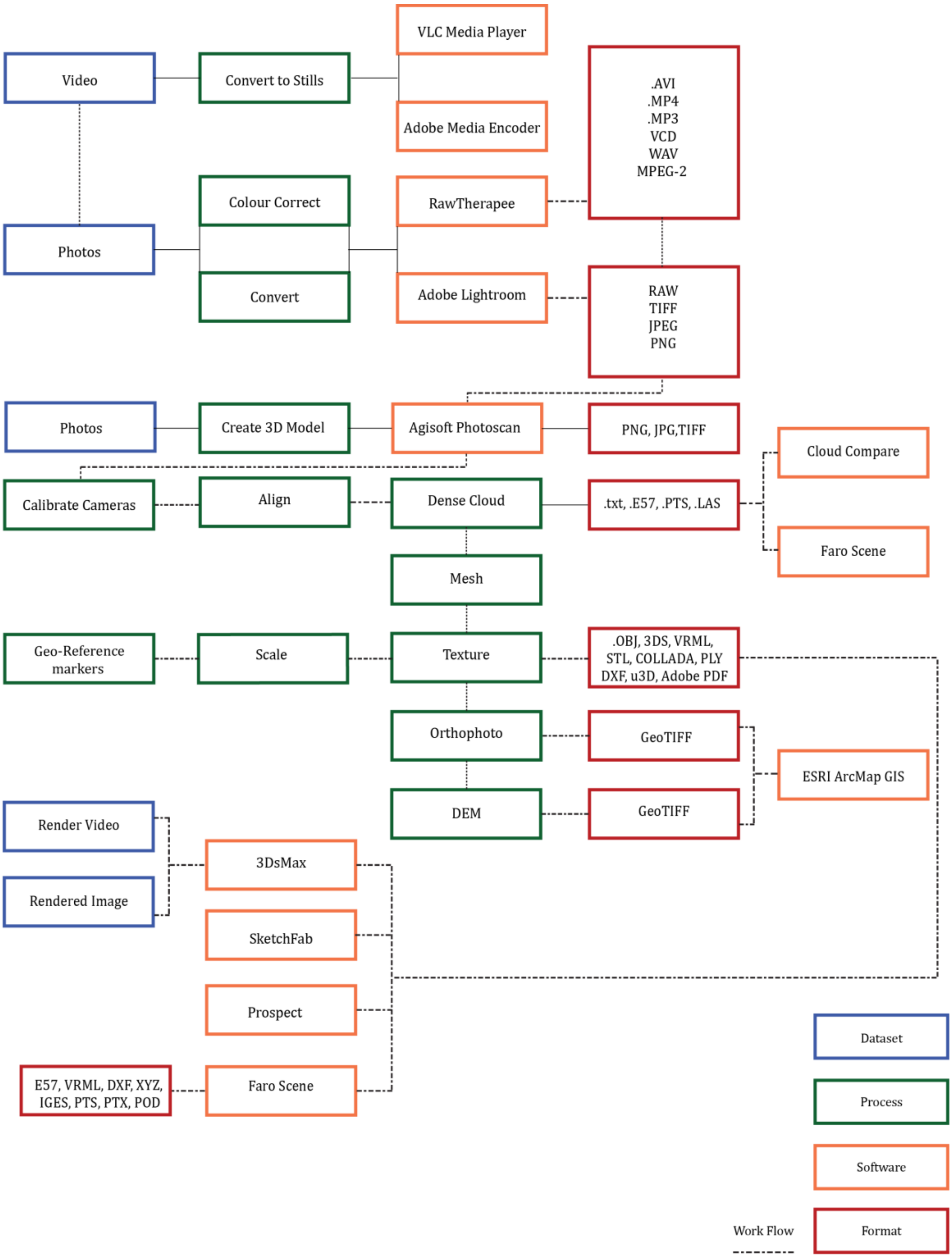

Figure 23. This figure explains the photogrammetry workflow followed by the author.

3.3.3.2 Positioning accuracy

Positioning accuracy of the 3D photogrammetric model and its sub-products point cloud, mesh, DEM, and orthophoto, relies on having a control point's network (CPN). The CPN was measured with direct survey measurement (DSM) that was created by Rule (Rule 1989), and later on, incorporated into a GIS platform by Holt (3H 2006, 2017).

Agisoft Metashape Pro ® has a series of individually numbered targets that are automatically detected on a model (Figure 24). These targets allow the software to have a unique reference point, for common tie-points between images and also used as control points so they can be used to scale a model. As the target has to remain on site for several months without moving, they were printed out on a durable surface of a composite panel called Dibond ®[102] or Forex®[103]. Additionally, these targets were printed on a matt surface, to avoid light reflecting during the recording stage, especially when using the artificial light source.

[102] Dibond White 9003 Gloss/Matt Sheet is a composite panel that combines two 0.3 mm high quality, aluminium surface layers with a UV resistant polyethylene core and comes with a protective film on both sides (Plastock 2018)

[103] Forex® is a fine white rigid PVC foam sheet composite. The advantage of using Forex ® over Dibond® is that the copper nails used to fix the targets to the wreck would not corrode the aluminium surface. This is an effect created by electrolysis between copper nails and the aluminium targets in a salt-water environment.

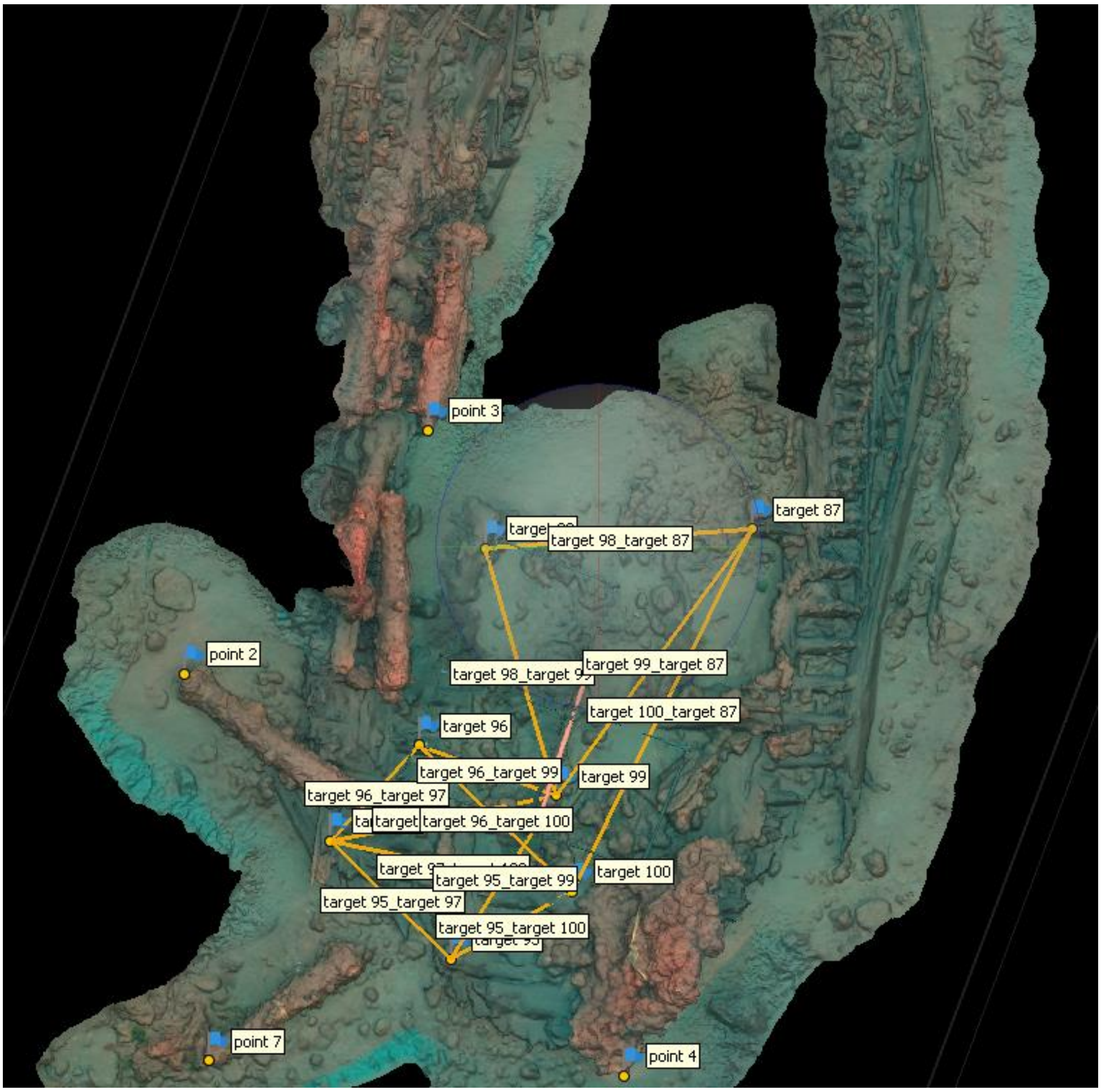

Figure 24. Target detection, scale and geo-referencing in UTMWGS48/30N. In Agisoft Photoscan Pro®.

Georeferencing, changes the model from local coordinates to a projected coordinate system, in this case, WGS84/UTM 30N. This way it is possible to take points from an MBES survey that are recognisable on the model and match them either on ArcMap® or Cloud Compare®. The points come from MBES data sets, where X, Y and Z values are reliable, and they have been calibrated previously (Fig. 26).

Agisoft Metashape Pro ® allows to calculate: easting (m), northing (M), altitude (M), accuracy (M), error (M), yaw (∘), pitch (∘), roll (∘), accuracy (∘), error (∘), projections (num), and error (pix)[104]. To guarantee the spatial accuracy of our models we have selected a series of additional Ground Control Points (GCP) based on the MBES surveys,

[104] Individual photographs will be called cameras (as it will have a position in reference to the model)

and recognisable with photogrammetry. This is the best way to guarantee global-positioning with several correcting methods RTK, POSPac®[105] and depth based on the tidal correction. Therefore, these points are set as markers with two primary objectives: To scale the model and to geo-reference and give a real z value, or depth.

3.3.3.3 Digital Elevation Models (*DEM*)

In Agisoft Metashape Pro ®, Digital Elevation Models (DEM) are produced by interpolating between the dense cloud points. This means that the quality, accuracy, scale, and geo-referencing of the DEM, will depend on the spacing between points in the dense cloud. On a micro-level analysis of analysing sediment migration, changes in volume and wood degradation this is a valuable tool. Therefore, to be able to compare deferent DEMs, it is important to establish control points with a CPN.

The resolution from the DEM obtained from MIP and specifically a close-range photogrammetric (CRP) survey will provide higher-detail than any MBES system. However, there is a limitation on what the diver, ROV, or AUV can cover, as well as the environmental conditions and visibility. Covering large areas of the seabed with an ROV or AUV, as UAVs[106] or planes do for terrestrial surveys, has great potential in clear water. The processing time of large photographic datasets would also be a challenge that can be overcome by network processing. The computing power needed to process large data sets is exponential and other software such as Reality Capture® allow having an unlimited amount of processing units with an algorithm that spread the load work by stages (Capturing Reality 2019). However, it was noted that Agisoft Metashape Pro ® works better for underwater data sets, as it is more forgiving with stitching the images[107]. Several tests were made using the same datasets from the case studies (*Hazardous, Rooswijk* and *Invincible*) and Agisoft Metashape Pro® produced better results overall.

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[105] Further explained in section 3.3.1.2
[106] Unmanned Aerial Vehicle (drone)
[107] The author of this thesis ran several test with Reality Capture® on the same datasets process with Agisoft Metashape Pro ® for the case studies.

Possibly, in future surveys, it will be possible to combine high-density point cloud data from MBES or Underwater laser scanner (ULS)[108] surveys with photogrammetry, as done for land surveys combining laser scanning and photogrammetry[109].

To monitor changes on site with the combination of DEMs from MBES and photogrammetry or any other survey technique it is essential to use the same resolution on the data sets or the same CPN.

It is important to understand that the best MBES resolution available for *Hazardous, Invincible* and *Rooswijk* was at best 20cm. The question is if that is enough to monitor micro-scale changes on site. 20cm of sediment movement can be critical for the preservation of archaeological material, and in particular mobile artefacts that will be lost during storms.

[108] Underwater Laser Scanner (ULS) are discussed in the next section, 3.3.4.2
[109] Examples for terrestrial surveys shown in section 3.3.4.1

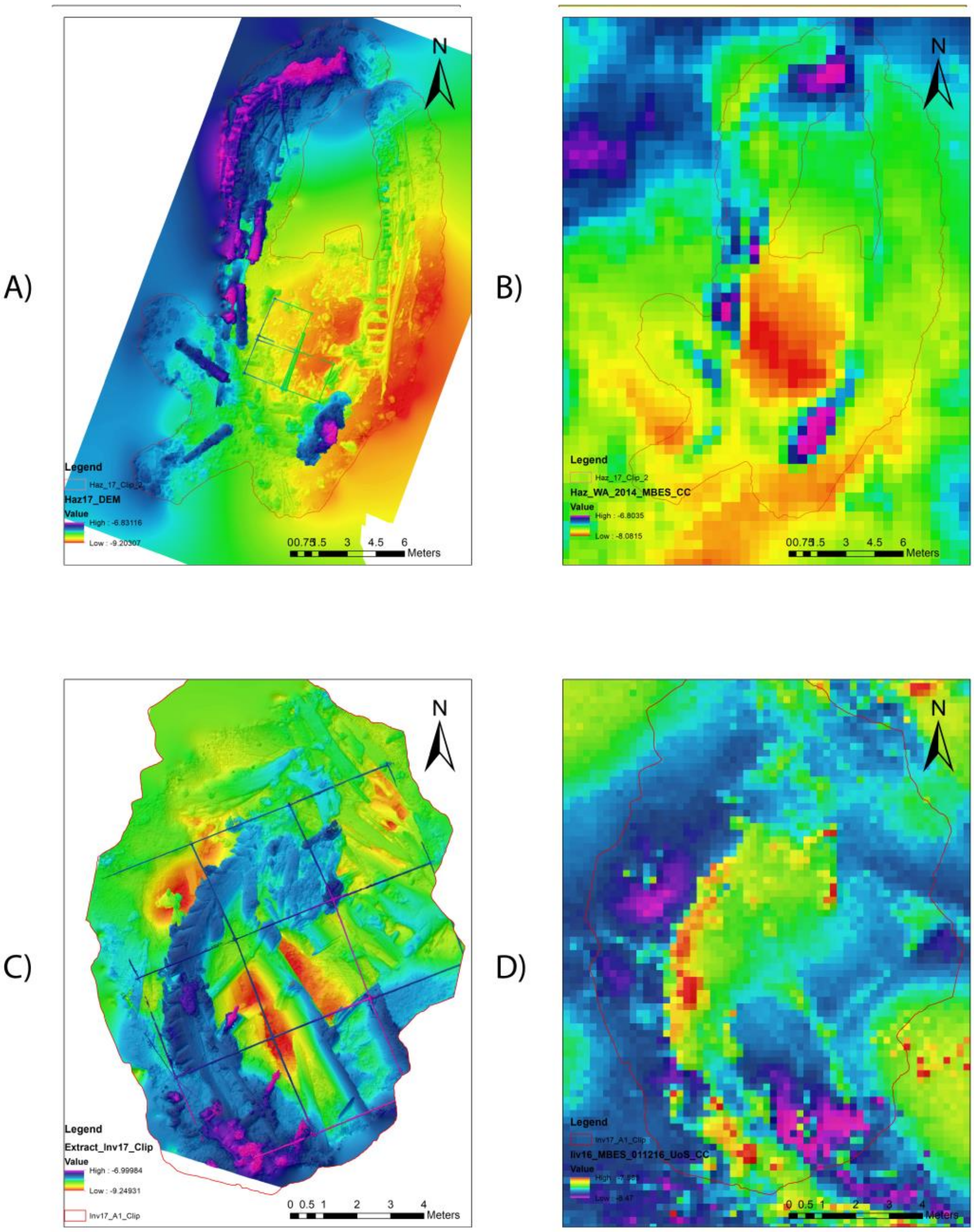

Figure 25. A) *Hazardous*, DEM with Hillshade from photogrammetry 2017 (left), and MBES WA 2014 0.2m resolution (right). B) *Invincible*, DEM with Hillshade from photogrammetry 2017 (left) and MBES UoS 2016 0.2m. Maps created on ArcMap10.5®.

3.3.3.4 Orthophoto

An orthophoto is a geometrical rectified composite image, from which it is possible to measure. The difference between an orthophoto and a conventional perspective aerial photograph is that the latter contains image displacements caused by the tilting of the camera (yaw, pitch and roll) and differences in the terrain relief. The effects of camera tilt and the underwater bathymetry are removed from the ortho creating a uniform-scale photograph (Danielson and Gesch 2011).

In Agisoft Metashape Pro ® unless the model is georeferenced, with the correct orientation (x, y and z) based on a GCP that is evenly distributed, the "top-down" view that is manually selected for the orthophoto or a DEM will be incorrect. Therefore, the need of using an MBES data as a reference to select the appropriate GCP's, using the real depth of the site explicitly represented in chart datum (CD) or Ordnance Datum Newlyn (ODN).

MIP survey's of extensive areas presents the challenge of producing large datasets of photographs. For example during 2018, on HMS *Invincible* in order to record an extensive excavation area, over 100 m^2, it was necessary to take 2456 pictures[110]. After adding twelve GCP and creating a CPN, the model was adjusted, orientated and scaled. Another challenge of creating an orthophoto of the extensive area is having a similar colour profile for all the pictures, even with post-processing with Adobe Lightrrom®. In Agisoft Metashape Professional ®, there is an option to enable colour correction, which will blend the differences between each picture while creating the orthophoto. However, there is a loss of resolution while trying to level out the changes in light that happen during the survey, even if the picture has been previously colour corrected. Post-processing in Adobe Photoshop® is an option to aid overcoming this problem (Fig. 28). While creating a texture, it has been observed that using smaller data sets, with a full-frame DSLR, colour can be controlled and resolution is considerably higher; to the point where even tool marks can be observed on the wood (Figure 27).

[110] Of which 2303/2456 aligned using Agisoft Metashape Pro®.

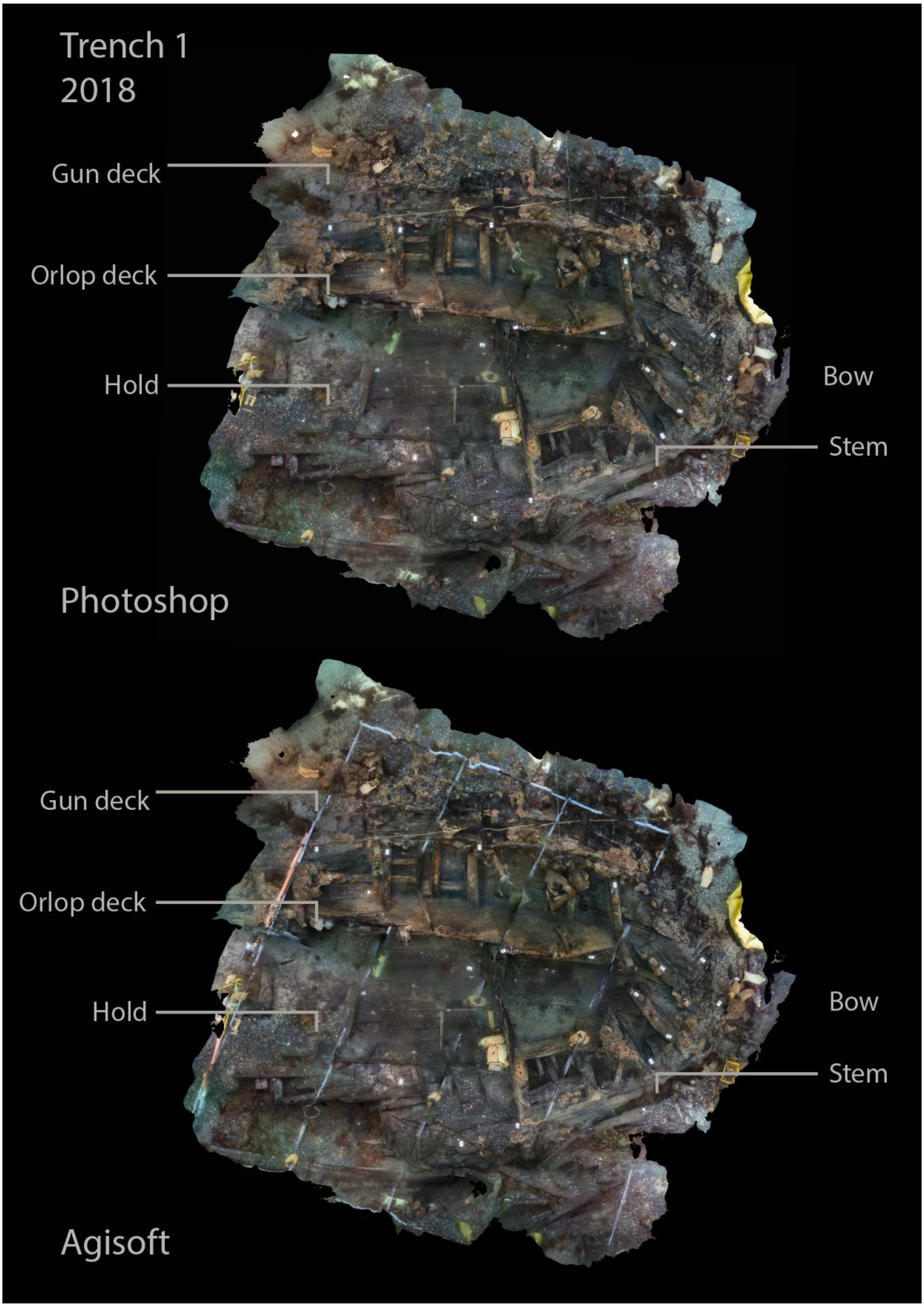

Figure 26. Orthophoto of the excavation of HMS *Invincible* 1758 colour corrected in Adobe Photoshop®. Exported directly from Agisoft Metashape Professional®. Full video animation is available at (https://vimeo.com/257165394), generated by the author on 3DsMax® and uploaded to Vimeo Inc. ™.

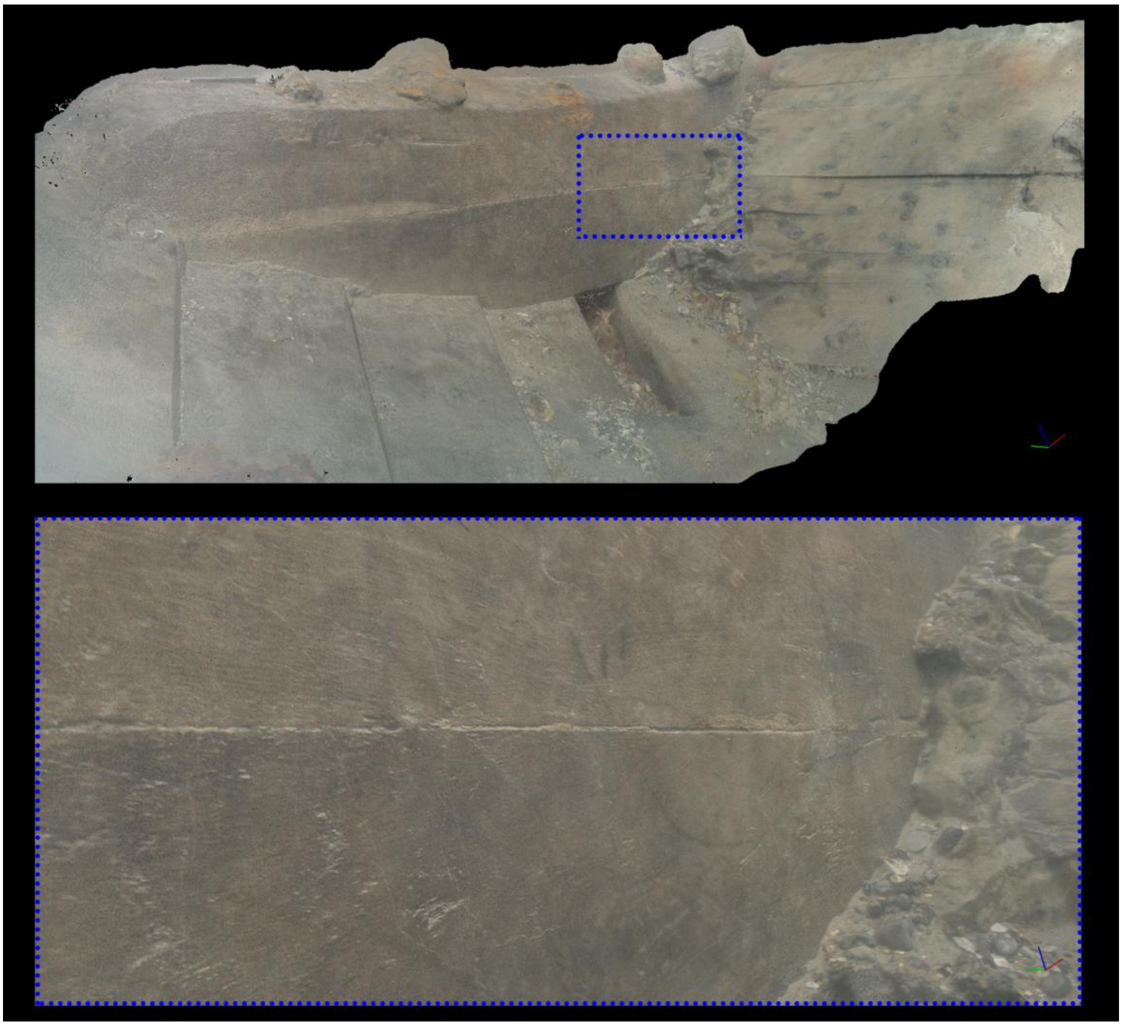

Figure 27. Photogrammetric model made with a Nikon D800 showing a rising knee from HMS *Invincible*, close-up. Created by the author with photographs taken by Mike Pitts used with permission from Bournemouth University and MAST.

3.3.4 Laser Scanning

3.3.4.1 Airborne laser systems (ALS)

Marco and mesoscale. Airborne laser systems (ALS) are an extremely useful surveying tool for coastal and more near shore environments. They can be used to map, land, floodplains, and shipwrecks in shallow waters (Flener et al. 2013; Kumpumäki et al. 2015; Mandlburger et al. 2015; Parker et al. 2012; Steinbacher et al. 2012; Tian-Tuan Shih, Ya-Hsing, and Jie-Chung 2014; Ventura 2012). Light Detection and Ranging (LiDAR) is a method that creates a 3D dataset of extensive areas with limited access or hazardous navigation for the survey operators (Nayegandhi 2006). It is because of these aforementioned facts that ALS systems have great potential to create bathymetric surveys of shoals, reefs, shallow water channels, or nearshore areas with other navigational hazards, with potential shipwrecks, submerged settlements or archaeological landscape studies (Figure 28).

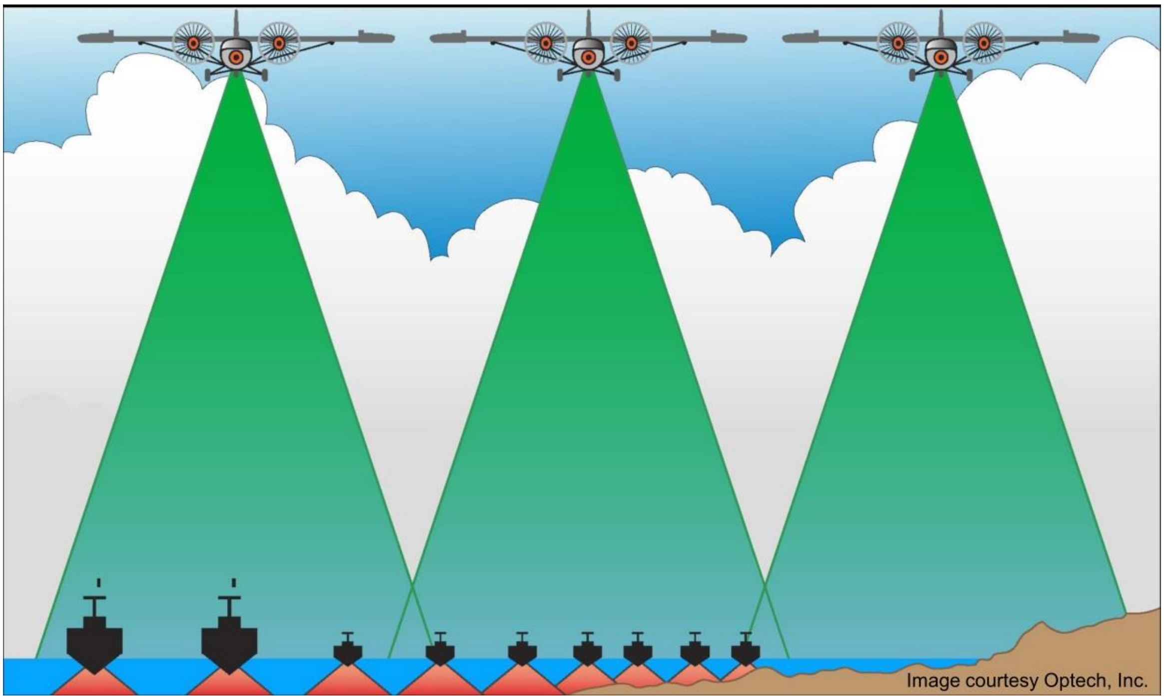

Figure 28. The image shows the difference in coverage with airborne and waterborne survey techniques. The image was obtained from Optech, Inc. from (Nayegandhi 2006)**.**

However, this technique has several limitations for surveying wrecks. Data resolution is severely limited by water depth and high water turbidity, which is a problem commonly found throughout British waters (mostly in riverine systems). The turbid zone represents a challenging area for maritime archaeologists in general. However, it has been demonstrated that wrecks generate Suspended Particulate Matter (SPM) concentration signals that can be detected by high-resolution ocean colour satellite data such as Landsat-8 (Baeye et al. 2016). Additionally, typical error sources in LiDAR include those from vertical reference (essential for sediment migration studies), data collection (pitch, roll, heave, and positioning datum), data processing, elevation change since collection, datum conversion, and data integration. The compound error of the end product could be substantial (Hadley, Marcy, and Raber 2007:15). However, for a general survey, it is possible to create a high-resolution digital terrain model (DTM) with a seamless boundary between land and water for river channels or floodplains. This can be done by combining with a low-altitude unmanned aerial vehicle (UAV), which creates a photogrammetric based surface and both a digital bathymetric model, searching for a seamless land-water contact (Flener et al. 2013). In the UK the only Airborne LiDAR data available is from the Scilly Isles, presenting a seamless coastline of the topography and bathymetry (Figure 29). It covers two Protected Wreck sites *HMS Colossus* and *Bartholomew Ledges* with one-metre resolution (Fig. 32). This large-scale survey provides a general context of the surrounding environment, that demonstrates the potential of Airborne Lidar Systems that should be further encouraged in suitable environments as demonstrated in other parts of the world (Dewberry 2013; Observatory 2018; Parker et al. 2012). This technique might be a viable option for the *Royal Anne* found in Lizard Point, Cornwall, where perilous waters make it difficult to carry out waterborne surveys (Camidge, Johns, and Rees 2006:13).

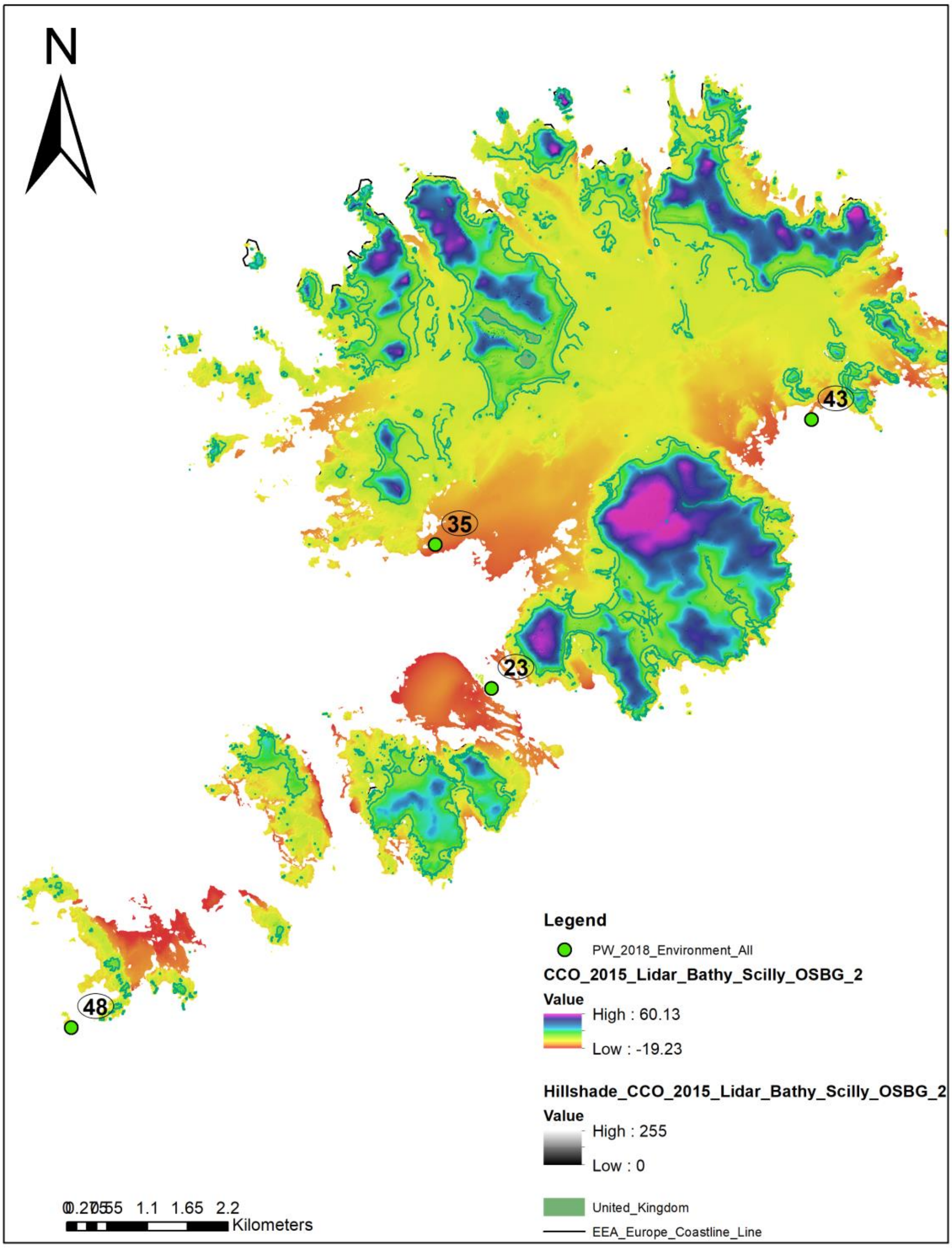

Figure 29. The map shows a LiDAR survey with 1 m resolution with a seamless coastline of the Isles of Scilly from the Coastal Channel Observatory done in 2015 (CCO 2018)**. The Protected Wrecks are 23. *Bartholomew Ledges*, 35. *HMS Colossus*, 43. *Wheel Wreck*, and 48. *Association*. The position of the wrecks was obtained from Historic England list of PW** (HE 2018b)**.**

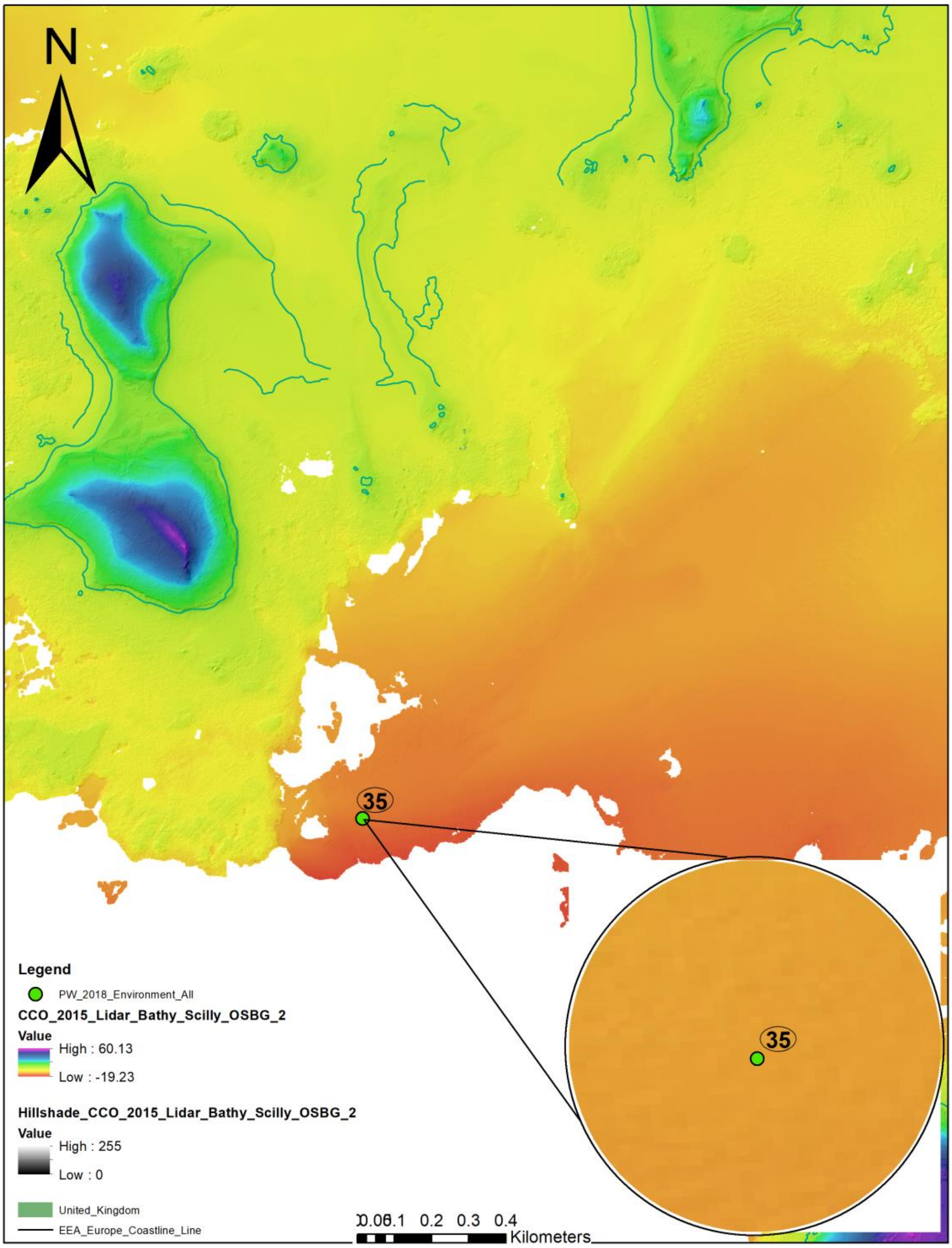

Figure 30. The map shows a LiDAR survey with a 1m resolution with a seamless coastline of the Isles of Scilly with a close up of *HMS Colossus*, data obtained from the Coastal Channel Observatory (CCO 2018)**. The position of the wrecks was obtained from Historic England list of PW** (HE 2018b)**.**

Unfortunately, for the three case studies presented in this thesis the use of LiDAR on *Hazardous, Rooswijk* and *Invincible* is impossible due to turbidity throughout the year (*Hazardous* and *Invincible*) and depth (*Rooswijk)*. Alternatively, the detection of shipwrecks and other submerged structures can be detected in ocean colour satellite imagery. Baeye *et al* (2016) demonstrated that wrecks generate SPM concentration signals that can be detected by high-resolution ocean colour satellite data such as Landsat-8. Baeye *et al* presented case studies where the SPM plumes extend downstream for up to 4 km from wrecks. However, it is important to notice that measuring SPM is a technique limited to areas with regular tidal pattern flows, and to areas with the coverage with adequate data resolution. The detection of wooden wrecks is also limited by the lack of standing structure remains in comparison to more substantial modern metal wrecks.

Aerial photography is a tool commonly used in archaeology that started as early as the mid 19th century in Europe. These photos where mainly reviews taken from hot-air balloons. During the 1st and 2nd World War higher-resolution orthophotography, and stereo-photogrammetry was used for surveying purposes (Ceraudo 2013). The use of planes to survey large areas is expensive, but it can produce high-resolution datasets. Nowadays, satellite imagery offers a wide range of multi-spectral datasets (including RGB/BW aerial photography) that are used for surveying even large areas; they can be used to understand landscape changes and the archaeological site or feature location. Many datasets are open source (Google 2019), accessible and relatively easy to use (Landsat, Modis, and Sentinel). By selectively adding or removing multispectral bands it is possible to highlight or exclude high-density vegetation, urban areas, or other targeted features.

In the past 5 years, the use of drones or Unmanned Aerial Vehicles (UAV) has become an increasingly popular tool to generate high-resolution terrestrial surveying for smaller area coverage (Shervais and Dietrich 2016; USGS National UAS Project Office 2017). UAVs have become more and more useful as other technology advances, decreasing in size and making portable devices such as a green bathymetric laser or multispectral cameras. This technique can become particularly useful in maritime archaeology, when surveying shipwrecks located in inland, coastal, intertidal and shallow waters with hazardous navigations and where access on boats is complicated, such as reefs, shoals, or sandbanks. However, this survey method is limited by the previously mentioned conditions of water turbidity and depth range. MBES systesm, airborne laser bathymetry (ALB), combined with another land surveys, such as laser scanning and photogrammetry, has been used to create a seamless land-water map (Mandlburger et al. 2015). However, this presents new challenges when using different positioning and depth datums for water bourne, or aereal surveys (USGS National UAS

Project Office 2017). Coverage depends on the UAVs time of flight, its cargo capacity, the equipment used and the type. In general terms, there are four types of UAVs: multi-rotor, fixed-wing, single-rotor, and fixed-wing hybrid (Chapman 2016).

3.3.4.1 Terrestrial Laser Scanning (TLS) and Close Range Scanning (CRS)

In the past decade, Terrestrial Laser Scanning (TLS) has been used more frequently for surveying due to its speed, simplicity and precision of acquired geospatial information (Klapa, Mitka, and Zygmunt 2017). Laser scanning is a type of data recording technology that enables the virtual capture of the built environment and other types of archaeological objects. The method has been used increasingly for cultural heritage recording as it allows for the collection of accurate metric surface data, as well as carry out an extensive structural analysis of historical buildings (Miles 2017). TLS is an active, fast and automatic acquisition technique that is carried out without any contact, and creates a dense regular pattern, 3D coordinates of points on surfaces (Grussenmeyer and et al 2016:306; HE 2018a:4). Phase-comparison systems have traditionally had much higher rates of data capture (greater than a million points per second) as a result of the emission of a continuous wave, but pulse scanners have caught up, at higher end specifications (HE 2018a:13).

3D laser scanners were first deployed in archaeological and heritage fieldwork almost 25 years ago (Cooper et al. 2018:319; Guidi 2014:37). However, in maritime archaeology, they are still rarely used. According to Cooper *et al* (2018:420), the first known endeavours of *in situ* recordings with a laser scanner was the Doel 1 cog found in Antwerp, Belgium, in 2000 (Haneca and Daly 2014; Van Hove 2005; Vermeersch and Haneca 2015). Laser scanning was carried out on some iconic projects for maritime archaeology *Vasa* in Sweden, and *Mary Rose* in the UK. However, the publication of these data sets is yet to be made. In 2019, Traditional Boats of Ireland and the author of this thesis scanned the *Mary Rose* and combined it with a photogrammetry survey (Tanner and Ortiz 2019), with plans to extend the survey in the future. For close range scanning (CRS) numerous project have deployed a Faroarm (FARO 2019) to record individual ships timbers or individual artefact in high detail (Jones 2009; Jones, Nayling, and Tanner 2013; Kocabaş 2015; Ozsait-Kocabas 2011; Vermeersch and Haneca 2015:114).

TLS and CRS offer exceptional speed, detail, and accuracy in the recording of complex watercraft (Cooper et al. 2018:329) to meso and intra-site level scales. Since ships and boats are three-dimensionally curved bodies of varying complexity (Crumlin-Pedersen and McGrail 2006:54; Tanner 2013:134), recording them accurately can be challenging. Having a 3D model allows further interpretation of the reconstructed vessel: the hull shape, establishing floating condition, spars and rigging (performance, stress, and functionality), steering (required area, based on modern standards), wind loading stability, assessment of performance, speed potential, propulsion, alternative methods of propulsion, cargo capacity and tonnage and seaworthiness[111] (Tanner 2012, 2013).

However, there are limitations to their use depending on the environment and/or material properties, for which alternative methods of hybrid modelling (a combination of several methods). For example on partially submerged structures that lie partly above the water line, TLS can be combined with MBES, MIP or ULS. Although the integration of LiDAR, MBES, TLS, MIP and ULS is still in initial phases, multiple technique approach will provide in the future better results for surveyors. Software companies such as Hypack ®, Quinsy® and EIVA ® are starting to offer plug-ins or suits that enable further data integration as a response to the need to enhance their data display and increase their capability for interpretations.

3.3.4.2 Underwater Laser Scanner (ULS)

Intra-site scale. Underwater Laser/LiDAR Scanner (ULS) are used as inspection tools in the industry because of their precision and versatility to mount onto ROV's, with minimal calibration. There are several ways of deploying a ULS, and they can be used stationary or in a dynamic survey collection mode. ULS has a wide range of equipment,

[111] The later term *seaworthiness* is a broad one (Tanner 2013:142):

the fitness of the vessel in all respects, to encounter the ordinary perils of the sea, that could be expected on her voyage, and deliver the cargo safely to its destination […] including the strength, durability and integrity of the hull, the freeboard at operational drafts, the stabilility and reserves of buoyancy (McGrail 2001:6).

depending on the type of recording, from handheld scanners CTS-3D diver laser scanner (SAVANTE 2017), stationary scanners[112] (2GRobotics 2017; 3D at Depth 2018b) to advanced deep-sea dynamic ULS-500 PRO® (2GRobotics 2017)or SL2® (3D at Depth 2018a) 3. They can be operated with different similar software to a MBES, such as Hypack ®, EIVA Marine Solution Survey®, or QINSYy®.

The high cost of operation is still a disadvantage for carrying out repetitive surveys to monitor on shallow shipwrecks, compared to photogrammetry. A stationary ULS requires calibration, excellent visibility and a fixed position for several hours. Hence, operation logistics of deploying a system like that in highly dynamic environments such as *Rooswijk* and *Invincible* are challenging. Murray carried out some trials on shallow water wreck site in Florida (Murray et al. 2017) with a 2G robotics ULS-200®, successfully exploring differences in accuracy depending on environmental conditions and its limitations. Another example of a 2G Robotics® ULS-500 (2GRobotics 2017) was an assessment survey for damage done on the *Costa Concordia* (Gray 2016), demonstrating a high-density point cloud. It is possible that in the future, this will become a cost-effective tool for maritime archaeology. However, it is not been demonstrated to be a cost-effective tool yet.

3.3.5.3 Structured Light Scanner (SLS)

Intra-site scale. The structured light scanner (SLS) was used on artefacts recovered from the *Rooswijk* excavation, in controlled lab conditions. An SLS allows high-resolution documentation, with sub-millimetric precision, enhancing features like tool marks, material type, production and post-depositional damage.

SLS uses a projector to illuminate the surface of the scanned object, a camera or cameras later captures the surface reflection.

The projection of a standardised pattern of light on the subject allows the pixel columns of the digital projector to be identified off the scanned surface, and measured resulting pattern from a different perspective used to produce a pattern deformation according

[112] Diver and ROV deployable, depending of depth.

to the shape of the object. By triangulating the points created from the pixel, it creates a surface of the artefact (Mostafa Abdel-Bary 2013:328; Pieraccini et al. 2001:66; Törnblom 2010:9)

Experimental Underwater SLS systems have been tested as experiments (Törnblom 2010), although they are not industry built, and still need development to be used commercially. Having been tested with several objects and to guarantee a scan with sub-millimetric accuracy, it is essential to control environmental and light conditions, as well not moving to object between scans (McPherron, Gernat, and Hublin 2009:19).

SLS has advantages over photogrammetry regarding ultra-high resolution and accuracy of surfaces, as demonstrated by statistical analysis between DAVID® SLS2 and photogrammetry (Maté-González et al. 2017). However, photogrammetry produces a much higher quality texture, that is important for documenting changes in pre and post-conservation. Another complication with SLS is calibration for differently sized artefacts or material types. This process is time-consuming, and therefore it is important to select carefully the artefacts that are recorded in this detail. Unfortunately, materials such as glass, were not possible to scan, because of light reflection, absorption and scattering. Another problem was scanning extremely flat artefacts, such as coins, which also represented a problem for the SLS, which struggled with understanding it had two sides.

The artefacts were scanned with a DAVID® SLS3 made by HP® on the *Rooswijk* 1740 Project (Table 11), e.g. pewter tankard recovered during the 2017 excavation on *Rooswijk* https://skfb.ly/6t7vY.

***Rooswijk* 1740 Project**					
Artefact	**ID number**	**Artefact**	**ID number**	**Artefact**	**ID number**
Jug	RK17 A00139	Tool Handle	RK17 A0022	Jug (neck)	RK17 A00029
Copper pipe	RK17 A0029	Pewter Jug	RK17 A0039	Pewter Spoon	RK17 A00133
Pewter Tankard	RK17 A00033	Oil Lamp	RK17 A00687	Tool Handle	RK17 A00089
Musket Plate	RK17 A00115	Pewter Inkstand	RK18 A00216		

Table 11. Inventory of 3D Models done with SLS on MSDS Marine Sketchfab (MSDS Marine Ltd and RCE 2017). With kind permission of RCE (https://sketchfab.com/msdsmarine).

3.4 Conclusions

This chapter explained the reasoning behind the selection of methods, their potential and limitations. This critical analysis looked at the capacity for better archaeological interpretations based on the techniques employed for documenting shipwrecks as well as their contribution to different scales of study (macro, meso and intra-site). The methods that were selected required an explanation of their basic principles, as well as the terminology used throughout the thesis, which are now better understood with this section. The methodology emphasised on the best standards with direct application to each case study *Hazardous, Rooswijk* and *Invincible.*

3.5 Further Research Data Integration

This chapter presented a critical review of methods used to record marine heritage and, as such, it explored the area for further potential and devolvement in data integration. Throughout this thesis, it is emphasised that there is a general trend to create better data integration from wide-ranging techniques, which allows filling the gaps left by each survey techniques' capabilities. Better documentation of cultural heritage benefits from this type of data integration or hybrid modelling. On land-based surveys, it has been observed that the hybrid approach the necessity to integrate the laser scanning technique and photogrammetry, is needed to improve the geometry and visual quality of the collected 3D model (Haala and Alshawabkeh 2006). There is high potential to integrate laser scanning and photogrammetry in order to improve the geometry and visual quality of the collected 3D model (Grussenmeyer et al. 2008; Klapa et al. 2017; Koch and Kaehler 2009; Siebke et al. 2018; Wilkinson et al. 2016)

Macro-scale hyperspectral[113] information provides optical oceanographers with the potential to accurately correct remote sensing images and classify complex oceanic environments (Chang et al. 2012:19). The main motivation for hyperspectral mapping of mineral distribution is the detection of ore deposits for mineral exploration purposes (Bierwirth, Blewett, and Huston 1998; van der Meer et al. 2012). In marine settings, hyperspectral methods have been used mainly in oceanographic and

[113] Hyperspectral imaging (HSI) is a spectral imaging acquisition where each pixel of the image was employed to acquire a set of images within certain spectral bands.

biological studies (Chang et al., 2004; Dickey et al., 2006), including mapping of ocean colour (Dickey and Lewis 2012; Dierssen and Randolph 2013) and seafloor habitats (Fearns et al. 2011; Klonowski 2007) such as reefs (Hochberg and Atkinson, 2000, 2003; Kutser et al., 2006; Petit et al., 2017), seagrass ecosystems (Dierssen 2013) and kelp forests (Volent, Johnsen, and Sigernes 2007). Finer-scale features can be mapped but this is depth-dependent given the inherent optical properties. The majority of sunlight penetrates no deeper than 50m into the water, the application of passive hyperspectral sensors in marine settings is limited to coastal areas and shallow water depths (e.g. Klonowski et al., 2007; Volent et al., 2007; Fearns et al., 2011). Hyperspectral methods can be used for archaeological purposes to characterise the seabed surrounding submerged sites, mapping out coastal areas and potentially identify more marine heritage.

However, as explained in this chapter underwater survey have further challenges determined by its environment. Nonetheless, with future improvement techniques may push the boundaries of our capability to survey underwater sites.

For example, many of the challenges of surveying with multi-image photogrammetry (MIP) will be the adverse light conditions that create shadows or poor visibility, which may be complemented with an underwater laser scanner (ULS) that is not light dependent

High-resolution data availability is key for the efficient application of any of the abovementioned techniques to record land, coastal or submerged marine heritage assets. Having an active role in generating new datasets is critical to understand how these sites change, as well as to present better management strategies. Therefore, the rapid changes in technology will make us have a continuous revision of our methods and technique to record marine heritage and ongoing critical reviews will be needed. Maritime archaeology will need to keep an eye on how other disciplines approach similar challenges and contribute to understanding specific marine environments in relation to UCH.

Chapter IV. Classifying Shipwrecks and their Environments

This chapter presents the challenges of classifying shipwrecks, critically analysing how we understand cultural heritage and how we classify it. Furthermore, this chapter provides a new dimension of maritime heritage assessment that includes marine environment dynamics for its classification. As discussed in Chapter III, the site formation processes are divided into natural processes (*n-factors*) and (c-factors). In the expanded flow diagram created by the author [114], the natural processes form a key component that can be measured in energy-levels that integrates physical, chemical and biological factors. However, due to the complexity of marine environments, it is necessary to explain each input (wave exposure and sea horizon, tidal currents, biozones, and substratum) and how this is relevant to understanding underwater maritime heritage.

As the aim of this thesis is to create an integrated methodology of site formation processes to aid in better archaeological interpretation, it is critical to include both the wrecks and their environments. Therefore, this chapter presents a new system of criteria that integrates environmental dynamics into wreck classification. This typology aims to be seamless and provide a macro-scale approach to UCH in the UK. Furthermore, the combination of both *c-factors* and *n-factors* provide a wider dimension for cultural heritage care and management to assess the wrecks' vulnerability and threats.

4.1 Wreck Site Classification or Typologies

In archaeology, it is common practice to typologically classify artefacts, or an assemblage of artefacts (Adams and Adams 2007:19, 24, 240; Hill and Evans 1972), such as boats (Mcgrail 1985; McKee 1972, 1983) or shipwrecks (Muckelroy 1978a:60–65). Such typologies are used as analytical tools that attempt to aid our understanding and interpretation of the archaeological record and its surrounding environment. These typologies are typically based on morphological, spatial and chronological (temporal) attributes. The first, a morphological typology, focuses on the physical

[114] See Figure 13 in Section 2.2

attributes of an object, and it can be further extended to an *etic* (functional classification), or an *emic* classification (intentional classification[115]). The second focuses on the spatial distribution of artefacts, relating each to a specific activity area[116] or geographical relationship (if this can be identified) (Manzanilla 2000:248; Pecci et al. 2018:485; Rondelli et al. 2014:482)[117]. The third, a chronological typology, is based on temporal factors such as when the artefact was created, used, abandoned or became part of the archaeological record (Adams and Adams 2007:91–96). All three of these typologies can be combined to understand the archaeological record, and the artefacts' temporal and functional relationship with an assemblage of an artefact such as a shipwreck. Typologies are essential for creating analogies between different archaeological sites, distinguishing their similarities and differences. However, typologies are also restrictive, and sometimes insufficient to categorise multi-functional or rapidly changing artefacts.

As stated above, the aim of this chapter is to present a large-scale analysis of the environments related to the Protected Wrecks sites of the UK and England in particular by evaluating the potential impact of environmental conditions on the shipwrecks' structural integrity and the dispersal of its remains. This approach draws on and builds on the system of evaluation for volcanic hazards and their potential impact on the landscape and populations (Van Eaton et al. 2012; Saucedo et al. 2005; Sulpizio et al. 2010), as they both require multifactorial analytical tools to understated broad environment dynamics. The shipwreck classification work similar to the ones used in human geography typologies are used to classify and measure the impact of human activity (population economic activity) in relation to the environmental (soil, climate,

[115] A classification related with the intention of the makers according to their "mental templates" or the uses for which the objects where created (Adams and Adams 2007:282; Deetz 1967:45–49; Watson, Le Blanc, and Redman 1984:208–10).
[116] Activity area is the minimal [observable] spatial unit of archaeological research, in which repeated social actions are reflected in particular concentrations and associations of raw materials, instruments, semi-processed products, and debris, which relate to particular production processes, use/consumption, storage and disposal (Flannery 1976:5-6; Manzanilla 1986:11; Manzanilla 2000:249). These observable units are also referred to as anthropogenic activity markers, where the use of space produces an accumulation of residues (chemical and/or physical) in the deposit, that represents the result of the activity that produced them (Rondelli et al. 2014:283; Pecci et al. 2018:485).
[117] View chapter VI on artefacts distribution for the *Rooswijk.*

topography), or *vice-versa* the impact of the environment on economic activities (EEA 1999; Hazeu et al. 2011; van der Zanden et al. 2016).

The objective of this macro-scale study is to correlate the archaeological record with the marine environmental condition (such as wave exposure, sea horizon, biozones, substratum and energy). These type of classifications present a proxy to understand sites with a higher environmental threat by physical, chemical and biological factors; this is critical for the assessment of condition and threats of maritime heritage.

In terms of heritage management at an institutional level, a formal ontology[118] is intended to facilitate the integration, mediation and interchange of heterogeneous cultural heritage information (Aalberg et al. 2019:i). In the UK the main standard for documenting heritage asset information is MIDAS Heritage[119] (2012; HE 2019a). MIDAS Heritage is a data standard for information about the historic environment[120]. It states what information should be recorded to support effective sharing and long-term preservation of the knowledge of the historic environment (English Heritage 2012:1). MIDAS Heritage incorporates elements from several different standards, such as spectrum DAM (data asset management)[121], UK Gemini Discovery Metadata Standard (GIS / geographic information)[122] and the International Committee for Documentation (CIDOC) Conceptual Reference Model (CRM)[123].

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[118] An ontology is a set of rules that categorizes these nodes into classes, and dictates which classes can be connected to each other. It's a "rulebook" for graph construction. Generally, this is known as a CRM (Conceptual Reference Model)

[119] MIDAS Heritage is a British cultural heritage standard for recording information on buildings, monuments, archaeological sites, shipwrecks and submerged landscapes, parks and gardens, battlefields, artefacts and ecofacts.

[120] The sum of physical changes made to the natural world by past human activities. Includes all types of heritage assets (English Heritage 2012:117)

[121] Spectrum gives tried-and-tested advice on the things most museums do when managing their collections of artefacts (Collections Trust 2019).

[122] The aim of UK GEMINI is to provide a core set of metadata elements for use in a UK geospatial metadata service, that are compatible with the INSPIRE requirements for metadata. The EU INSPIRE Directive2 mandates the collection of metadata for use in Europe (Association for Geographic Information 2012)

[123] The International Committee for Documentation (CIDOC), formally known as *Comité International pour la Documentation*. CIDOC CRM is an international standard (ISO 21127) providing definitions and a formal structure for describing the implicit and explicit concepts and relationships used in cultural heritage documentation.

The primary role of the CRM is to enable information exchange and integration between heterogeneous sources of cultural heritage information. Increasingly the CRM is being used to provide a common framework for the sharing of information across disparate datasets. MIDAS Heritage is intended to provide a specific application of the CRM appropriate to the needs of the UK historic environment community. It, therefore, adopts some terminology derived from the CRM (English Heritage 2012:13).

Several national bodies and cultural institutions that catalogue and document cultural heritage have developed different forms, standards and glossaries (Lozano 2001; Niccolucci, Ronzino, and Amico 2011): ICCD form, (Italy)[124], MIDAS Heritage standard (UK) [125], the inventory of the French Cultural Heritage based on the *Schéma Documentaire Appliqué au Patrimoine et à l'Architecture* (SDAPA), the Visual Research Association (VRA Core)[126], International Council on Monuments and Sites (ICOMOS)[127] and CIDOC CRM[128].

However, even in the UK where institutions follow national or international standards of recording and documenting cultural heritage, there are dissimilarities between databases depending on their objectives. Specifically with regards to terms, glossaries, categories and legal status. Therefore, a closer insight with a critical evaluation of how we record and understand UCH is needed, and on wrecks in particular. Furthermore, none of the above-mentioned heritage classification systems or modules makes a reference to the localised context or surrounding environment of an artefact, an

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[124] ICCD defines standards and tools for the cataloguing and documentation of national archaeological, architectural, art history and ethno-anthropological heritage in agreement with the regions (Niccolucci et al. 2011)

[125] MIDAS is a data standard for information about the historic environment, developed by the English Heritage, for and on behalf of the Forum on Information Standards in Heritage (FISH).

[126] VRA Core is a data standard that consists of a metadata element set (units of information such as title, location, date, etc.), as well as an initial blueprint for how those elements can be hierarchically structured. The element set provides a categorical organization for the description of works of visual culture as well as the images that document them (VRA 2007).

[127] The Principales for the recording of Monuments, groups of buildings and Sites of the International Council on Monuments and Sites (ICOMOS) (1996).

[128] CIDOC CRM is a formal ontology that defines CH documentation concepts and the relationship between them, used to clarify the documentation process, and to ensure no loss of semantic content when integrating heterogeneous Cultural Heritage data sources.

assemblage of artefacts, or a site (such as a shipwreck). This is a major gap in our knowledge and is generally overlooked by museums or general heritage classification. Hence, this chapter evaluates the multi-disciplinary approach to create a shipwreck classification that includes its environment to a larger degree.

4.1.1 Chronological Typologies or Time Period

A crucial element of creating effective heritage management strategies is establishing a consented glossary or vocabulary (*thesauri)* for the description of cultural heritage. HE has acknowledged this is a concern and adopted the *thesauri* established by FISH[129], with the main focus on developing content and data standards for use in the heritage sector [130].

Considering the standardisation on criteria for documenting heritage assets, another critical factor that is taken into account when classifying shipwrecks is the time period to which they belong. These chronological typologies to classify wrecks in the UK are diverse, as they vary depending on the organisation that deals with them. This is important to consider, as it demonstrates that there are no set criteria for the UK, and the subperiods vary widely, especially in prehistory. For example, the periods used by Wessex Archaeology on the pre-historic to 1840, for early ship and boats (ESB) database (Wessex Archaeology 2013b), are as follows (Appendix I):

- Early Prehistoric (500,000 – 4,000 BC)
- Late Prehistoric (4,000 – 54 BC)
- Roman (54 BC-AD 410)
- Post-Roman to Norman Conquest (410 AD – 1066)
- Medieval and Early Tudor (1066 – 1540)
- Mid to Late Tudor (1540 – 1603)

[129] The Forum on Information Standars in Heritage (FISH) was established in 1998 as a discussion forum for heritage organizations. Tracing its origins back to the Data Standards Working Party, its main focus has been on developing content and data standards for use in the heritage sector (Heritage Data 2019).
[130] Other databases have adopted Arches[130] v.3 adopted by EAMENA, particularly with regard to the development of new CIDOC CRM resource data models, reference data, and modifications to the Arches codebase (Zerbini 2018).

        - Stuart (1603 – 1714)
        - Hanoverian (1714-1837)

The main problem with the ESB by WA (2013b) is the overly simplified and broad categories, especially in the prehistoric period, with no concern for distinguishing between Palaeolithic, Mesolithic, Neolithic, Bronze Age, and Iron Age. This would be an essential category for understanding early human settlement in relation to the archaeological record of maritime activities. The ESB period system ends in 1840 at the beginning of the Victorian Period; it does not consider the following periods that are relevant for modern wrecks including the 20th century that eventually will become of historic relevance.

For this thesis and future shipwreck classification in the UK by the cultural time period the following HE's classification that is more inclusive of specific periods (HE 2018d):

- Prehistoric
    - Palaeolithic (500,000 – 10,000 BC)
    - Mesolithic (10,000 – 4,000 BC)
    - Neolithic (4,000-2,200 BC)
    - Bronze Age (2,200-800 BC)
    - Iron Age (800 BC-AD 43)
- Roman (AD 43-410)
- Early Medieval (410-1066)
- Medieval Period (1066-1540)
- Post-Medieval Period (1540-1901)[131]
    - Tudor Period (1485-1603)
    - Elizabethan Period (1558-1603)
    - Stuart (1603 - 1714)
        - Jacobean Period (1603-1625)
    - Hanoverian (1714-1837)
        - Georgian (1714-1830)
- Victorian Period (1837-1901)
- 20th Century (1901-2000)
    - Early 20th Century (1901-1932)

[131] Modern world period 1492-present (Orser 2016: xvii).

        - Edwardian (1902-1910)
        - First World War (1914-1918)
    - Mid 20th Century (1933-1966)
        - Second World War (1939-1945)
    - Late 20th Century (1967-2000)
        - Cold War
- 21th Century (2001-2100)[132].

Any type of chronological typology that categorises the archaeological record will be biased and subject to review, and ships or boats are no exception. The mobile character of a complex assemblage of artefacts, such as a ship, adds an extra challenge to placing them into a specific chronological period. For example, *Invincible* 1744-1756*,* originally a French ship, could fit into the Bourbon Period of France. However, she is catalogued as a ship of the Hanoverian or Georgian period, because she was captured in 1747 and served until 1758 in the British Navy (Bingeman 2010:5–6). The purpose of providing a chronological period is to provide information about the wreck and to relate it to other wrecks of the period. How representative would it be to call the *Invincible* it a Georgian wreck? Another example is the *Rooswijk* (1738-1740)*,* as she wrecked in British waters by chance on her way to Batavia (modern-day Jakarta). If we catalogued her as Hanoverian it would be misleading, as she never had interaction with a British port, and no one knew where she wrecked until 2005 when she was discovered. Therefore, it is important to take caution with any chronological typology, however, it is important to have a common terminology to be able to compare between wrecks of the same period. As Adams pointed out, technological innovation in shipbuilding is a far better indicator of ships' transition periods, from Medieval to Early Modern (Adams 2013a:55–98).

The time period used by HE (2018d) is adequate for regional studies within the UK. However, if the larger macro-scale area included wrecks of continental Europe then these time periods will become irrelevant. By using simpler and neutral time-periods this problem could be overcome, such as 15th or 16th centuries.

[132] The chronology is based on HE guidelines (HE 2018b).

4.1.2 Morphological Typologies or Craft Type

Morphological typologies or craft type form another classification of wrecks, although again these will vary widely depending on the time period and the region. The craft type classification can be a comparative feature between wreck sites around the world. For example, *Rooswijk* can draw important analogies with another VOC merchantman from the archaeological record such as: the *Batavia* 1629 (van Duivenvoorde 2015), *Kennermeland* 1664 (Archaeology 2006; Muckelroy 1976a)*, the Hollandia* 1743 (Cowan, Cowan, and Marsden 1975; Gawronski, Keist, and Stokvis-van Boetzelaer 1992), *Zuiddorp* 1712 (Van Duivenvoorde et al. 2013), *Zeewijk* 1727 (Ingelman - Sundberg 1977), *Adelaar* 1728 (Martin 2005), *Vligenhart* 1743 (Pol 1993) and *Amsterdam* 1748 (Gawronski 1990; Marsden 1974). But also from historical sources by comparing it to other *hekboot*[133] types of Dutch ships[134] (Jong 2010; De VOC site 2018).

Some craft types that are artificial categories, such as a *Hulk*, can be misleading categories. As demonstrated by Adams (2013a:99–110) a *Hulk* has no solid archaeological evidence as a craft type. Therefore, some of these morphological typologies must be critically analysed before being used. Another problem rises while only using historical sources[135], where some craft type name can be inter-changed

[133] The *hekboot* (sternship) was a mixture between a *fluit* and a *pinas* (pinnace). The lower hull was formed like that of a *fluit*, while the superstructure was designed after the *pinas*, and therefore much wider than the original *fluit* design. The result was an increased carrying capacity and more generous accommodation for the crew (Laan n.d.; De VOC site 2018).

[134] *Agatha* (1721), *Alblasserdam* (1725), *Alsem, Van* (1732), *Boot* (1733), *Civetkat* (1679), *Delft, Hof van* (1739), *Drakestein* (1680), *Duine Huis Ter* (1739), *Flora* (1730), *Graveland's* (1722), *Groet* (1732), *Haamstede* (1730), *Hartenlust* (1734), *Herstelling* (1721), *Horssen* (1739), *Horstemeer* (1677), *Kerkzicht* (1735), *Knappenhof* (1731), *Langerode* (1723), *Leeuwerik* (1741), *Leiduin* (1730), *Meermond* (1730), *Naardermeer* (1677), *Nederhorst* (1671), *Nieuwburg,'t Huis Te* (1697), *Noordwolfsbergen* (1733), *Oegstgeest* (1699), *Overnes* (1696), *Pallas* (1723), *Phoenix* (1739), *Polanen* (1737), *Proostwijk* (1730), *Reigersbroek* (1726), *Romein* (1677), *Rust en Werk* (1734), *Ruyven* (1736), *Spijk, Huis te* (1732), *Stabroek* (1722), *Strijen* (1735), *Susanna* (1721), *Venenburg* (1734), *Voorduin* (1732) *ex Zorgwijk* (1730), *Voorduin* (1732) later *Zorgwijk* (1732), *Vreeland* (1735), *Vrijheid* (1740), Watervliet (1736), *Westbroek* (1681), *Westerbeek* (1722), *Zorgwijk* (1730) later *Voorduin* (1732) and *Zorgwijk* (1732) ex *Voorduin* (1732).

[135] *Galleons (galeón), galleot (galeota)* , *galley (galera*)*, schooner* (*goleta*)*, galeasse* (*galeáza*), *brig* (*bergantín*), *sloop* (*balándra*) and other ship types to mention a are terms used indiscriminately by the untrained eye to distinguish the differences.

indiscriminately by the person creating the document. Using a variety of sources (archaeological, historical or anthropological) to corroborate the craft type is preferable, although not always possible.

In the UK, the diversity of craft types used to classify boats and ships in different databases will vary considerably depending on the period that these vessels were built in:

- Pre 1848, EBS (Merchant Vessel, Boat Burial, Historic Vessel, Logboat, Other craft.
- Historically significant, HE (*Carrack*, Submarine, Warship, *Galley*, and other craft.
- Post-1915, MOD (military ships, frigate, submarine, aircraft carrier, destroyer, assault, patrol and minehunters, Royal fleet auxiliary, and survey vessels) (MOD 2018).
- All wrecks in British waters, UKHO (Oil tanker, bulk carrier, ferry, military ship, trawler, other craft).

4.1.3 Typologies by Legal Status

The legislation is another relevant classification when looking at the wider picture of how wreck sites are protected in the UK, including the British Overseas Territories (BOT) and in other parts of the world.

The legal status of wrecks is determined by location, ownership, protection, designation, and/or salvage rights under international treaties and state jurisdiction. However, it is important to recognise that effective protection of UCH relies on state jurisdiction,[136] therefore it varies widely depending on where the UCH is located (Mackintosh 2018:7). The current foundation of this is set out in United Nations Convention on the Law of the Sea (UNCLOS)[137], which outlines a number of maritime zones and the jurisdiction available to states within them (*idem*). Therefore, the

[136] The state has to be able to regulate the behaviour of actors and enforce relevant regulations effectively to protect UCH (Mackintosh 2018:7).
[137] More than 160 State Parties and the EU (Therefore the UK as well).

location (such as Territorial Seas[138], EEZs[139] or International Waters) of the wreck is critical, as this will determine the legal status of the wreck, and under which laws it may be regulated (UN 1982a). Consequently, the protection it may receive is dependent mostly on the ships period, location, craft type, and ownership or Flag State[140] (MOD 2014; The Crown Estate 1995).

In the UK, selected historically valuable vessels fall under the Protection of Wrecks Act 1973[141] (Crown 1973) and Marine Protected Areas Act 2016[142] (Historic Environment Scotland 2016). Other modern 20th and 21st century wrecks with no historical value fall under the Merchant Shipping Act 1995 (Recent wrecks, with no historical value). Based on their environmental impact (Dangerous[143], pollution[144]), there are special considerations for the legal responsibilities of the vessel's owner (Wrecks Authority 2012).

Military wrecks in the UK and Overseas fall under the Protection of Military Remains Act 1986 (MOD restricted area post-1915)[145]. In the UK there are 12 Designated Controlled Sites and 79 Designated Vessels (MOD 2017).

However, there are different criteria used throughout the British Isles (and British overseas territories (BOT)) that represent advantages and disadvantages. Within the boundaries of the Isle of Man Territorial Waters (12 miles offshore), there are 1,126 recorded shipwrecks (Johnson et al. 2013:12) and 1 protected wreck site[146] (under the Protection of Wrecks Act 1973; (Johnson et al. 2013:16; WA 2005:51).

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138 The area automatically appurtenant to a coastal state, extending up to 12 nautical miles from coastal baselines (UNESCO 2015:23)

139 EEZ Exclusive Economic Zone, an area beyond and adjacent to the territorial sea, extending no further than 200 nautical miles from the baselines (UNESCO 2015:23).

140 Flag State
The state to which a non-commercial vessel belongs or under whose laws a commercial vessel is registered or licensed (UNESCO 2015:23)

141 England:53, Wales:6, and Northern Ireland: 1. See full list in Appendix I

142 Scotland: 8

143 SS Richard *Montgomery* and SS *Castilian*.

144 Risk factor (Minor, moderate and serious) (Alcaro et al. 2007:21–23)

145 The Secretary of State for Defence can make a statutory instrument designating as a controlled site any area in UK or international waters which appears to him to contain a place comprising the remains of a vessel, or aircraft which appears to him to have sunk or been stranded while in military service..
The vessel has to have less than 200 years elapsed since the sinking or stranding.

146 HMS *Racehorse* 1822 (Johnson et al. 2013:16)

In the Channel Islands (Jersey, Guernsey, Alderney, Sark, Herm, Jethou, and Brecqhou), there is specific legislation that regulates the Wreck and Salvage of vessels and aircraft (The Royal Court of the Island of Guernsey 1986), for an estimate of 392 shipwrecks around Guernsey (David, 1962; Sharp, 1968) and an equivalent number in Jersey (Orbasil and Chowne 2013:10).

In the BOT[147]legislation varies noticeably (Ministry of Defence 2010:2). Considering that the BOT extends around the globe and comprises almost 13,500 nautical miles of coastline and 480,000 nm^2 of land mass (compared to the 11,000 nm and nearly 72,000 nm^2 for the UK and Crown Dependencies), they are much overlooked for their UCH potential and value. Only St Helen[148] (St Helena Government 2017), Bermuda (Ministry of the Environment, E-Commerce 2001; Wrecks Authority 2012) and Falkland Islands (The Crown Estate 1977) including their protectorates of South Georgia and South Sandwich (The Crown Estate 1985), have explicit legislation regarding historic wreck sites.
In the case of Bermuda, their Protected Historic Wreck sites (2001) are divided into open access (38) and closed access (13) for divers (Billy et al. 2007; Wrecks Authority 2012).

However, the UNESCO Convention on the Protection of Underwater Cultural Heritage (2001) offers a solution under international Law (Guérin 2019) that work in harmony with articles 3,149 and 303 of UNCLOS (1982a)[149] .

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[147]Anguilla, Bermuda, British Antarctic Territory (BAT), British Indian Ocean Territory (BIOT), British Virgin Islands (BVI), Cayman Islands, Falkland Islands, Gibraltar, Montserrat, Pitcairn, Henderson, Ducie & Oeno Islands, Saint Helena, Ascension and Tristan da Cunha (including Gough Island Dependency), South Georgia and the South Sandwich Islands, Sovereign Base Areas (SBAs) Akrotiri and Dhekelia (on Cyprus), and Turks & Caicos Islands (Ministry of Defence 2010:2).
[148] *Papanui, Spangereid, Darkdale, witte Leeuw* (White Lion), *Bedgellet, Frontier and Portzic,* and *Atlantic Rose*.
[149] *All objects of an archaeological and historical nature found **in the Area** shall be preserved or disposed of for the benefit of mankind as a whole, particular regard being paid to the preferential rights of the State or country of origin, or the State of cultural origin, or the State of historical and archaeological origin (*UNCLOS 1982 art 149)

The UNESCO convention (2001) is composed of the main text and an annexe, which sets out the "Rules for activities directed at underwater cultural heritage". It aims to provide a detailed State cooperation system and provide widely recognized practical rules for the treatment and research of underwater cultural heritage

The main principles of the UNESCO Convention (2001) are set out under basic tenets for the protection of UCH:

- The obligation to preserve UCH[150]
- *In situ* preservation as the first option[151]
- No commercial exploitation[152]
- Training and information sharing[153]

The 2001 Convention sets standards, considered as archaeological best-practice, to be applied to all activities directed at UCH (Grenier 2006; Mackintosh 2018:38). These are contained in the Convention's Annex and have to be applied to interventions on UCH no matter what maritime zone the UCH is located in (Mackintosh 2018:38). In order to function the regime relies on four 'pillars' of jurisdiction: cooperation and collaboration (coordinated jurisdiction), Flag State and nationality jurisdiction, port state jurisdiction and coastal state (territorial) jurisdiction (Mackintosh 2018:38; Rau 2002:434).

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[150] States Parties should preserve underwater cultural heritage and take action accordingly. This does not mean that ratifying States would necessarily have to undertake archaeological excavations; they only have to take measures according to their capabilities. The Convention encourages scientific research and public access (UNESCO 2001).
[151] The *in situ* preservation of underwater cultural heritage (i.e. in its original location on the seafloor) should be considered as the first option before allowing or engaging in any further activities. The recovery of objects may, however, be authorized for the purpose of making a significant contribution to the protection or knowledge of underwater cultural heritage (*Idem*).
[152] The 2001 Convention stipulates that underwater cultural heritage should not be commercially exploited for trade or speculation, and that it should not be irretrievably dispersed. This regulation is in conformity with the moral principles that already apply to cultural heritage on land. It is not to be understood as preventing archaeological research or tourist access (*Idem*).
[153] States Parties shall cooperate and exchange information, promote training in underwater archaeology and promote public awareness regarding the value and importance of Underwater Cultural Heritage (*Idem*).

However, it might be in the UK interests to join and ratify the UNESCO (2001) convention, and specifically considering the British Overseas?

A committee formed by British Academy (BA)[154], Honor Frost Foundation (HFF) (2014) and later reinforced by Firth (2018) argue a strong case that the UK should ratify the 2001 UNESCO Convention as the best means for protecting UK interests in wrecks that lie in international waters. The provision for shipwrecks in which the UK has an interest that lies outside UK territory is patchy and contested (Firth 2018). However, by expanding the protection of only wrecks (1973) into the protection of UCH over 100 years, as established by UNESCO (UNESCO 2001:2), possibly this would benefit some sites will benefit of better protection, but also raise other problems[155]. For example, Irish legislation automatically protects all wrecks found, even if they are unknown or their archaeological significance is unknown (Kirwan 2010; Open Data Unit 2018). This means that the assignation of resources for these wrecks are unbiased when a level bias is needed to distinguish wrecks that are more in need of research or excavation such as those with more historical significance or those at higher risk of loss (See maps in Appendix I). Furthermore, should we put in the same category an 18th-century shipwreck (eg. *Invincible* (Bingeman 2010; Pascoe 2013)) with loose finds (eg. Erme Ingot (Loughman 2007; Pink 2016:26))[156]? Or a submerged prehistoric site? These questions will possibly be answered in the near future concerning UCH in the UK and BOT.

For the purpose of this thesis, the category of Protected Wreck, under the act of 1973 (Crown 1973), used by HE has been extremely useful for classifying the most historically significant wrecks in British waters and specifically in England (Full list in Appendix I). A general evaluation of the site formation processes of the protected wreck sites in the UK was possible by integrating both natural and cultural processes.

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[154] The British Academy (BA) and Honor Frost Foundation (HFF).
[155] Underwater Cultural Heritage (UCH) refers to traces of human existence which have been partially or totally underwater, periodically or continuously for at least 100 years. It forms an integral part of a common global archaeological and historical heritage and can provide invaluable information about culture, economies, migration, and societal inter-relationships.
[156] Such as it has been done under the Protection of wreck Act 1976 (see Appendix I for list of PW sites).

4.1.4 Protected Wreck Site at Risk

The aim of this thesis is to provide better archaeological results that will lead to better strategies for cultural heritage care. Therefore, it is necessary to have a critical overview of the current evaluation systems used to classify Protected Wreck sites considered as at risk. There are currently 53 designated wrecks under the Protection of Wrecks act 1973 in England (Crown 1973; HE 2019b). Of the Protected Wreck sites, it was possible to distinguish the wrecks at high risk (HE 2017b, 2017a), of which two (50%) were chosen as case studies[157] as they offered the possibility of a full multiple-scale study. For HE, managing risks involves foreseeing areas of uncertainty and planning appropriate countermeasures consistent with the intention to study and assess the risks to historic assets and to devise appropriate responses (HE 2017a:1). To do this HE considers three broad factors:

- Condition[158] (optimal condition, generally satisfactory, generally unsatisfactory or having extensive problems).
- Vulnerability[159] (natural and anthropogenic influences on the site)
- Trajectory[160] (management regime)

The condition and vulnerability categories delineated by HE (HE 2017a:1) are intrinsically related to the site formation processes of the wreck site, including both cultural and natural factors. The holistic research methodology presented in this thesis addresses both the condition and vulnerability.

The trajectory factor is a qualitative assessment of site management strategies that requires further insight to the combined work of licensees, governmental institutions and agencies, charities, marine contractors, universities, ownership (wreck and seabed[161]), the impact of other industries on wreck sites (fishing, trawling, dredging,

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157 *Invincible, Rooswijk, London,* and *Northumberland.*
158 The current condition of the wreck, whether in optimal condition, generally satisfactory, generally unsatisfactory or having extensive problems (HE 2017a:1).
159 An assessment of the natural and anthropogenic influences on the site (*Idem*).
160 An assessment of the management regime, and whether the monument condition is improving, remaining stable or experiencing unmanaged or inappropriate decline (*Idem*).
161 See field number 14 in Table 12

salvage, transport, navigation, development, or recreational) and physical accessibility[162] . Even though the management strategies go beyond the scope of this thesis, by addressing how we can better understand both the condition and vulnerability this represents an important contribution for better cultural heritage care.

The recording fields presented by HE (Table 12) are intended to assist an assessor in making objective judgments relating to the condition of a wreck site (HE 2017a:5). Additionally, these recording fields are intended to have a standardised system of evaluation to designate resources to the most vulnerable cultural heritage assets.

HE established categories to assess the Protected Wreck at risk. Even though there are similarities between the categories created by HE and the ones presented in this thesis, having a holistic understating of site formation processes allows expanding these categories considerably.
The recording fields for this assessment that work in synergy with the multiple level approach in this thesis are (Table 15):

- Location, from 1 to 8
- Type, from 9 to 11
  - 9. Class listing[163]
  - 10. Period[164]
  - 11. Status[165]
- Setting from 12 to 17
- Condition (amenity value) from 24 to 26
- Management from 27 to 28
- Risk assessment[166]

The recording fields that could be expanded based on the methodology presented in this thesis are (Table 12):

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[162] See field number 25 in Table 12
[163] Discussed in section 4.2.1
[164] Discussed in section 4.2.2
[165] Discussed in section 4.2.3
[166] With amendments derived from better archaeological interpretation

- Setting
    - 18. Seabed Sediment
    - 19. Energy
- Condition (fabric[167])
    - 20. Survival (percentage)
    - 21. Fabric (overall condition)
    - 22. Fabric (overall trend)
    - 23. Fabric (principal vulnerability)
- 24. Amenity[168] value (principal visibility)

Field number	Field Name	Comment
Location		
1	Wreck (or site) name	Default: unknown
2	SI number	Text (where applicable)
3	NRHE[169] or UKHO[170] UID	Number
4	HE territory	Select from list [171]
5	Latitude (WGS 84)	Number
6	Longitude (WGS84)	Number
7	Restricted area (size)	Number
8	Principal land use	Select from list[172]
Type		
9	Class listing	Use Maritime Craft Thesaurus
10	Period	Select from list[173]

[167] The structure or parts of something that hold it together
[168] Something intended to make life more pleasant or comfortable.
[169] Historic England National Record of the Historic Environment (NRHE).
[170] United Kingdom Hydrographic Office (UKHO).
[171] East Midlands, East of England, London, North East, North West, South East, South West, West Midlands and Yorkshire & the Humber (HE 2017a:7).
[172] **Coastland 1**marine, **Coastland 2** inter-tidal, **Coastland 3** above high water, **Coastland 4** saltmarsh, **Coastland 5** cliff and related features, and **Coastland 6** other (HE 2017a:7).
[173] Uncertain, early prehistoric (-500,000 to -4000), late prehistoric (-4000 to 43), Roman (43 - 410), early medieval (410 - 1066), medieval (1066 - 1540), post-medieval (1540 - 1901), Tudor (1540 - 1603), Stuart (1603 - 1714), Hanover (1714 – 1837), Victorian (1837 – 1901), modern (1901 – 3000), pre-WWI (1914 - 1918), WWI (1914 – 1918), inter-war (1919 – 1938), WWII (1939 – 1945), post-WWII (1945 – 3000) (HE 2017a:8).

11	Status	Select from list[174]
Setting		
12	Licensee	Text
13	Nominated archaeologist	Text
14	Principal ownership category	Select from list[175]
15	Seabed Owner	Select from list[176]
16	Navigational administrative responsibility	Default: Nil
17	Environmental designations	Select from list[177]
18	Seabed sediment	Select from list[178]
19	Energy	High, Medium and Low (H, M or L)
Condition (fabric)		
20	Survival	Select from list[179]
21	Fabric (overall condition)	Select from list[180]
22	Fabric (overall trend)	Select from list[181]
23	Fabric (principal vulnerability)	Select from list[182]

[174] **A** Protection of Wrecks At 1973, **B** Ancient Monuments & Archaeological Areas Act 1979, **C** Protection of Military Remains Act 1986, **D** non-designated wreck site and **E** unknown (HE 2017a:8).

[175] **A** Private (individual), **B** Private (trust or company), **C** Crown/MoD, **D** Government or agency, **E** other (HE 2017a:8).

[176] **A** Crown Estate, **B** Private ownership, **C** Public ownership, **D** other and **E** unknown (HE 2017a:9).

[177] **A** Marine Conservation Zone (MCZ), **B** wetlands of international importance designated under the Ramsar Convention (RAMSAR), **C** areas that have been given special protection under the European Union's Habitat Directive (SAC), **D** strictly protected sites classified in accordance with Article 4 of the EC Directive on the conservation of wild birds (SPA), **E** the country's very best wildlife and geological sites (SSSI), **F** Marine Nature Reserve (MNR), **G** Other, **H** NONE no environmental designation (HE 2017a:9)..

[178] Based on Folk classification, see section 4.1.4 (HE 2017a:9).

[179] Percentage of material loss (PML). **Very good** PML <20% (Survival >80%), **Good** PML 21-40% (Survival 61-80%), **Medium** PML 41-60% (Survival 41-60%), **Poor** PML > 80% (Survival <20%), **Very Poor** PML >80% (Survival <20%) and **Unknown** (HE 2017a:10)**.**

[180] **A** Optimal, very little erosion, or no erosion, deterioration or other damage. **B** Generally satisfactory but with minor localised problems, 15% of localised damage to monument, **C** Generally satisfactory with 25% localised damage to monument, **D** Generally unsatisfactory with major problems, sever localised damage, **E** Extensive significant problems, with 50% widespread damage, and **F** Unknown (HE 2017a:10).

[181] **A** Improving, typically as a result of ongoing management, **B** Declining, **C** Stable, and **D** Unknown (HE 2017a:10).

[182] **ANGL**, recreational angling, **BAIT** bait digging, **FISH** fishing ground, **POT** potting (fishing method for lobster and crab), **SHELL** are of seabed with shellfishery rights, **TRAWL**, trawling, **BIO** biological decay, **C_ERO** coastal erosion, **CLIM** climate change,

Condition (amenity value)		
24	Amenity value quality: visibility	Select from list[183]
25	Amenity value quality: physical accessibility	Select from list[184]
26	Amenity value quality: intellectual accessibility	Select from list[185]
Management		
27	Management action	Select from list[186]
28	Management prescription	Select from list[187]
29	Data Source	Select from list[188]
30	Date of last visit	dd/mm/yyyy
31	Risk assessment date	dd/mm/yyyy
32	Compiler	Text

ECOL benthic ecology, **MECH** mechanical degradation, **S_ERO** seabed erosion, **NAT** natural decline, **ACC** authorized access, **DEV** development, **DIVE** unlicensed / unauthorised diving, **DUMP** dumping ground, **DRED** capital or maintenance dredging, **LICE** licensed aggregate extraction area, **LINE** pipeline / cable route, **MIL** military practice area, **SALV** clearance / salvage operations, **TRANS** transport route, **NKT** unknown threat, and **OTH** other (HE 2017a:11).

183 **A** substantial above-bed structural remains that are highly visible and 'legible' without further information, **B** limited above-bed structural remains and finds scatter with limited visibility and only 'legible' with further interpretative information. **C** not visible: only buried remains survive, **D** Unknown (HE 2017a:11).

184 **A** Full, **B** Restricted, **C** under licensees permission, **D** Nil or prohibited and **E** Unknown.

185 **A** Developed interpretative scheme (information board, leaflet, display/exhibition, guided tour, audio tour, guidebook and reconstruction. **B** Limited, **C** no interpretation and **D** unknown.

186 **A** no action required (routine monitoring, by the licensee / archaeological contractor **B** action implemented **C** action identified / agreed but not implemented and **D** action to be identified / agreed.

187 **A** formal management agreement, **B** Marine Heritage Partnership agreement, **C** HE Grant assistance / commission, **D** Local Heritage Initiative, **E** management agreement / grant funded by local authority or other qualified body, **F** other grant scheme or development proposal with explicit consideration of historic environment of the wreck site, **G** HE to influence local plan policies/liaise with local authority planners, **H** HE to laisse with owner/other stakeholder concerned to improve management regime, **I** refer to DCMS to review/ consider de-designation, **J** refer to DCMS to review / consider extension or reduction of restricted area, **K** condition survey required, **L** more regular condition monitoring, **M** no management prescription required, and **N** other

188 **AS** aerial survey, **CA** County Archaeologist, **CON** contractor (archaeological), **GEO** geophysical / AUV survey, **HARPO** Heritage at Risk Projects Officer, **IAM** Inspector of Ancient Monuments, **LAC** Local Authority curator, **LIC** Licensee, **MCA** Maritime and Coastguard Agency (Civil Hydrography Programme), **NOM** nominated archaeologist, **OT** other.

33	Risk: a field assessment	High, Medium or Low (H, M or L)
Notes		
34	Notes	Text

Table 12. The table summarises the Wreck Sites at Risk assessment carried out by HE, including footnotes (HE 2017a:5–6)**.**

The Energy level is critical to understand environmental dynamics and the impact it will have a wreck during different stages. The integration of wave exposure and sea horizon, tidal currents, biozones, substratum (seabed sediment[189]) enable an understanding and classification of the marine environments' energy levels (high, moderate and low)[190]. This macro-scale approach requires refinement based on meso and intra-site observations. However, it differs substantially from simply classifying the environment based on the licensee or marine contractor's criteria.

The assessment of historic wreck sites is based primarily on current fabric condition (survival[191]) and on change over time (observed and anticipated fabric overall trend[192]) (HE 2017a:3). From the subcategories within the fabric of the wreck the survival condition is measured in percentage[193], which is difficult to determine even by carrying out extensive surveys and excavations on buried sites in particular.

The fabric[194] (overall condition) is a management-led category, where it goes from optimal conditions to extensive problems with damage that lead to several structural problems. As explained during section 2.2 of site formation processes of wrecks, these act as open-systems with erosion cycles that can go through periods of relative stability. Therefore, this category requires specific long, meso and short-term trends. This idea ties in with fabric (condition trend)[195] that the wreck's condition goes from improving, declining, stable or unknown, either by management strategies or environmental dynamics.

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[189] See field number 18 in Table 12.
[190] See section 4.1 of this chapter.
[191] See field number 20 in Table 12.
[192] See field number 22 in Table 12.
[193] See field number 20 in Table 12.
[194] See field number 21 in Table 12.
[195] See field number 22 in Table 12.

In this thesis, the extent of structural remains and their integrity along with artefact survival and their distribution pointed out by Muckelroy (1978a) are key diagnostic tools to understand the site formation process on a wreck. They should be considered while understanding the fabric (overall condition) of the wreck.
The fabric value of principal vulnerability is strictly linked to both natural and cultural site formation processes[196]. Whether the deterioration of the wreck is mechanical, biological, or chemical erosion, the impact of the environment will depend on the energy level of the site. If the site is vulnerable due to human activity (fishing, trawling, dredging, anchoring or other activity[197]) then it is important to distinguish those factors for better management and care of the UCH, by mitigating or preventing further damage.

The amenity value of principal visibility[198] results in a troublesome category to define. This could be summarised in the fabric value of the condition. Due to the environmental dynamics, some sites are in waters with more or less visibility that will define how much structure is 'visible' depending on the surveying techniques used on different levels. For example, on the *Rooswijk*, the whole extent of the site is defined by looking at a mesoscale MBES analysis. Whereas on an intra-site level, the artefact distribution is only possible by using a USBL system during an extensive excavation[199]. This is the case on other wreck sites, with challenging high-energy environments and buried structures or artefacts (eg. *London, Invincible*, *Northumberland* or *Stirling Castle* to mention a few). The fact they are not 'legible' will rely heavily on extensive surveys and/or excavation with adequate recording methods, even if the archaeological remains are buried.

A quick risk assessment[200] of activities having an impact on a wreck is qualified as high, medium or low (H, M or L) with a system that considers the *impact* on the wreck site and the *probability of occurrence* (HE 2017a:1). The schematic representation (Table 13) shows green as Low risk, yellow as Medium risk and red as High. For example, if

[196] See field number 23 in Table 12.
[197] See field number 23 in Table 12.
[198] See field number 24 in Table 12.
[199] The methodology is further discussed in Chapter III, and site specific analysis on the *Rooswijk* in Chapter VI.
[200] See field number 33 in Table 12.

the impact is high but the probability of occurrence is low, then the risk is Medium. However, if the impact is high and the probability of occurrence is high as well, then the assessment marks it as high risk (red).

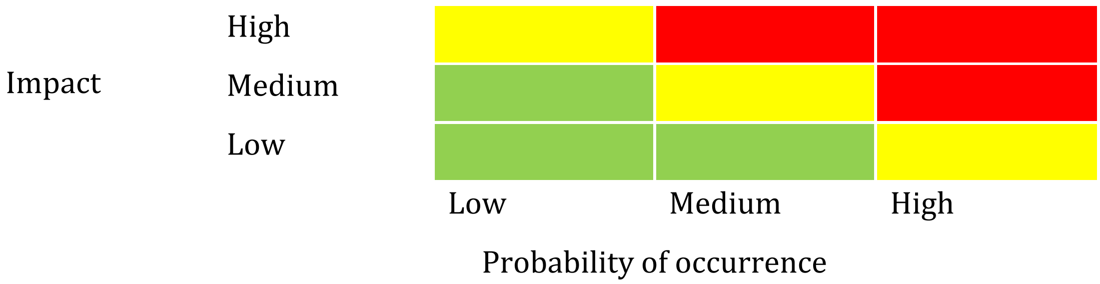

Table 13. The schematic representation of risk in relation to impact (consequence) and the probability of occurrence. Low risk is zoned green; the medium risk is zoned yellow; and high risk is zoned red (HE 2017a:1)**. The figure was created by the other of the thesis based on HE** (2017a:1)**.**

The degree of risk to the archaeological remains or surviving fabric of a historic wreck is measured by two methods. First a 'sieve' method, whcih is applied by assigning a point based system focusing on four principal attributes: visibility, fabric condition, fabric condition trend and fabric vulnerability (HE 2017a:13). Considering the above-mentioned issues that can be addressed for these attributes the point-based system could be improved.

The second method is a 'decision-tree' [201] (*idem*) that relies heavily on a series of broad assumptions, the capacity to evaluate changes and trends as well as the more recent qulity assessment or visit of the wreck site (HE 2017a:13). The decision tree provides a yes or no answer that is linked to the information obtained in Table 13 and Appendix I, which progressively lead to determining the level of risk (high, medium or low). Overall the question guides the assessment (e.g Does the site comprise completely buried remains? Or is the site of imminent exposure?). However, the greatest problem with this system is assuming that a management plan or a licensee will counteract the environmental impact on the wrecks' decay or erosion, instead of considering the energy levels, and state of preservation and trend with real data (remote sensing). Therefore, even if there is a licensee or a management plan, a multiple scale assessment will bring to light the impact of the environment on the wreck site and the future trajectory. This is the only real method of determining whether the wreck is stable, in decline or under accelerated decline.

[201] See full Risk Assessment tree and Risk Assessment template in Appendix I.

4.2 Marine Environment

The evaluation of risk, threats and erosion to a wreck must consider the environmental data available for the area in which the site lies.

Forty years ago Muckelroy (Muckelroy 1978a:160–65) had envisioned a site classification system based on marine environmental dynamics and its direct impact on a shipwreck. His scientific approach, based on coastal geomorphology studies (King 1972) presented environmental attributes and their degree of significance regarding its impact on site as follows (Muckelroy 1978a:162):

1. Maximum offshore fetch, within 30° of the perpendicular to the coast.
2. Sea horizon from the site; i.e. the sector within which there are more than 10 kilometres of open water.
3. Percentage of hours during which there are winds of Force 7 or more from directions within the sea horizon.
4. The maximum speed of tidal streams across the site
5. Minimum depth of the site.
6. Maximum depth of the site.
7. The depth of the principal deposit on site.
8. The average slope of the sea-bed over the whole site.
9. Underwater topography: the proportion of the site over which the sea-bed consists of geologically recent sedimentary deposits.
10. Nature of the coarsest material within these deposits.
11. Nature of the finest material within them. In ordering sites on this attribute and the previous one they were ranked initially according to broad categories of material, and then according to the relative importance of these deposits on the different sites.

Muckelroy gathered what he considered to be the essential aspects to classify and analyse the shipwrecks' environment. However, Muckleroy did not have the same data available, developed and adapted from other disciplines, that are available nowadays.

The EUSeaMap[202] created by EMODnet[203] (EMODnet 2016, 2018; Populus et al. 2017) presents a macro-scale (broad-scale) model of the underwater environments of the UK and other parts of Europe. The resolution varies between regions, but this systematic study offers an excellent proxy for specific regions and evaluates the impact of the environments on shipwrecks. This thesis uses this model as a general reference to characterise all the Protected Wrecks in England, with a careful comparison at a meso-scale with the case studies *Hazardous, Rooswijk and Invincible* (further explained in Chapters V, VI, and VII). The macro-scale approach to describe the marine environment classification is based on the above-mentioned system that Muckelroy (1978a:162) had proposed. The main difference with the newly proposed model, lies on a critical analysis of the techniques, methods and data availability (EMODnet (2016, 2018), BGS[204] (BGS 2006, 2018b; Bide et al. 2013; Long 2006), CCO[205] (CCO 2018), and BODC[206] (2018b), Digimap[207] (Edina 2018), EEA[208] (2018) and CEFAS[209] (CEFAS 2018; Devlin et al. 2009)) in the region used to understand the environment.

Muckelroy (1977) based his model on twenty wrecks[210] around the UK that he considered having enough information to be classified. This was the first systematic approach to understand site formation processes that included marine environment factors. Over forty years have passed, and there is much more information available on wrecks (PW) around the UK as well on data to model environmental dynamics.

The macro-scale approach in this thesis presents a new classification system based on energy levels by integrating the natural formation processes (physical, chemical and biological) that affect a wreck (Figure 13). The macro-scale model includes fetch, sea

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202 A European Broad-Scale Seabed Habitat Map
203 EMODnet: The European Marine Observation and Data Network.
204 BGS: British Geological Service
205 CCO: Channel Coastal Observatory
206 BODC: British Oceanographic Data Centre
207 Maps and geospatial data for the UK, hosted by the University of Edinburgh
208 EEA: European Environmental Agency
209 CEFAS: Centre for Environment Fisheries and Aquaculture Science
210 **1** *Kennemerland* (1664), **2** *DeLiefde* (1711), **3** *Trinidad Valencera* (1588), **4** *Adelaar* (1728), **5** *Darmouth* (1690), **6** *El Gran Grifón* (1588), **7** *Lastdrager* (1652), **8** *Girona* (1588), **9** *Santa María de la Rosa* (1588), **10** *Santo Christo de Castello* (1667), **11** *Mary Rose* (1545), **12** *Penlee* cannon site (1690?), **13** *Low Lee Ledges* (?), **14** *Mewstone Ledges* (?), **15** *Amsterdam* (1749), **16** *Hollandia*, **17** *Wendela*, **18** *Curaçao*, **19** *Eustafii* (1780), **20** *Colossus* (1798).

horizon, wind, tidal streams, depth, underwater topography and geomorphology to determine areas of Low, Moderate and High energy[211]:

1. Wave exposure (fetch[212], an average of wind speed and direction on site, openness and depth)
2. Sea horizon from the site (sheltered or exposed)
3. Tidal streams across the site (strong or weak)
4. Seabed morphology, depth of site (minimum, maximum and average) and underwater topography (slope[213])
5. Biozone[214]
6. Substratum (sedimentary deposits)
    a. *Coarsest material*
    b. *Finest material*
7. Sediment mobility

4.2.1 Wave exposure and sea horizon

Wave exposure takes into account the aspect of the coast (related to direction of prevailing or strong winds), the fetch (distance to nearest land), its openness (the degree of open water offshore) and its profile (the depth profile of water adjacent to the coast) (Connor et al. 2004:12; EMODnet 2016:33; JNCC 2018). The EUSeaMap classification range is as follows:

- **Extremely exposed**. This category is for the few open coastlines which face into the prevailing wind and receive oceanic swell without any offshore breaks (such as islands or shallows) for several thousand kilometres and where deep water is close to the shore (50m depth contour within about 300m).

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[211] The main factors which control the zonation are immersion, thermal stability, light, wave action and salinity (Connor et al. 2014:23)
[212] *Fetch is the distance over water that the wind blows in a single direction. If wind speed is slow, only small waves result, regardless of wind duration or fetch. If the wind speed is great but it only blows for a few minutes, no large waves will result even if the wind speed is strong and fetch is unlimited. Also, if strong winds blow for a long period of time but over a short fetch, no large waves form. Large waves occur only when all three factors combine* (Duxbury and Duxbury 2002; NOAA 2018b).
[213] Determining the average slope depends on the seabed topography
[214] These definitions primarily relate to rocky habitats or those where algae grow

- **Very exposed**. These are open coasts which face into prevailing winds and receive oceanic swell without any offshore breaks (such as islands or shallows) for several hundred kilometres but where deep water is not close (>300m) to the shore. They can be adjacent to extremely exposed sites but face away from prevailing winds (here swell and wave action will refract towards these shores) or where, although facing away from prevailing winds, strong winds and swell often occur.
- **Exposed**. At these sites, the prevailing wind is onshore although there is a degree of shelter because of extensive shallow areas offshore, offshore obstructions, a restricted (>90°) window to open water. These sites will not generally be exposed to strong or regular swell. This can also include open coasts facing away from prevailing winds but where strong winds with a long fetch are frequent.

- **Moderately exposed**. These sites generally include open coasts facing away from prevailing winds and without a long fetch but where strong winds can be frequent.

- **Sheltered**. At these sites, there is a restricted fetch and/or open water window. Coasts can face prevailing winds but with a short fetch (<20km) or extensive shallow areas offshore or may face away from prevailing winds.

- **Very sheltered**. These sites are unlikely to have a fetch greater than 20km (the exception being through a narrow (>30°) open water window, they face away from prevailing winds or have obstructions, such as reefs, offshore.

- **Extremely sheltered**. These sites are fully enclosed with fetch no greater than about 3km.

- **Ultra sheltered**. These sites have a fetch of a few tens or at most hundreds of metres.

4.2.2 Tidal currents

This includes the maximum tidal current strength which affects the actual area surveyed with a range as follow (BODC 2018a; Connor et al. 2004:44; EMODnet 2018) (Table 14):

Surface Tidal Streams	**Speed**	**Kinetic (Nm^2)**	**EUNIS Energy category (See section 4.1.5)**
Very strong	>6 knots (>3 m/sec.)	> 4.5	High
Strong	3-6 knots (>1.5-3 m/sec.)	1.16 - 4.5	
Moderately strong	1-3 knots (0.5-1.5 m/sec.)	0.13 - 1.16	Moderate
Weak	<1 knot (<0.5 m/sec.)	<0.13	Low
Very weak	Negligible	Negligible	

Table 14. The table shows the tidal streams threshold and categories for EMODnet (EMODnet 2018; McBreen et al. 2011).

4.2.3 Biozones

The macro-scale study of biozones provides a general idea of the marine life that can be expected on wrecks depending on depth, luminance, salinity, temperature, and seabed substratum. However, to specify the environment on each wreck requires further analysis at an intra-site level (Ferrari 1994:204; Ferrari and Adams 1990; Leino et al. 2011; Palma 2005; Pascoe 2013:19–20). Nonetheless, characterising biozone is relevant to the site formation process study because of the differentiated biological growth depending on the environment condition and levels of current biological activity (Ferrari 1994:204). All the Protected Wrecks in this thesis lie within the (A)

Littoral and (B) Sublittoral (a. Infralittoral and b. Circalittoral) zones (see Table 15 and Figure 31). Other shipwrecks that lie in deeper water with bathyal and abyssal biozones will be subject to different types of biological decay that will determine the state of preservation.

The biozones are a proxy to understand the level of biological decay based on the environmental condition that enable or restrict conditions for life to bloom (bacteria, fauna and flora). This is particularly important for the preservation of organic material found on historic shipwrecks (wood, leather, textiles, food, etc.)

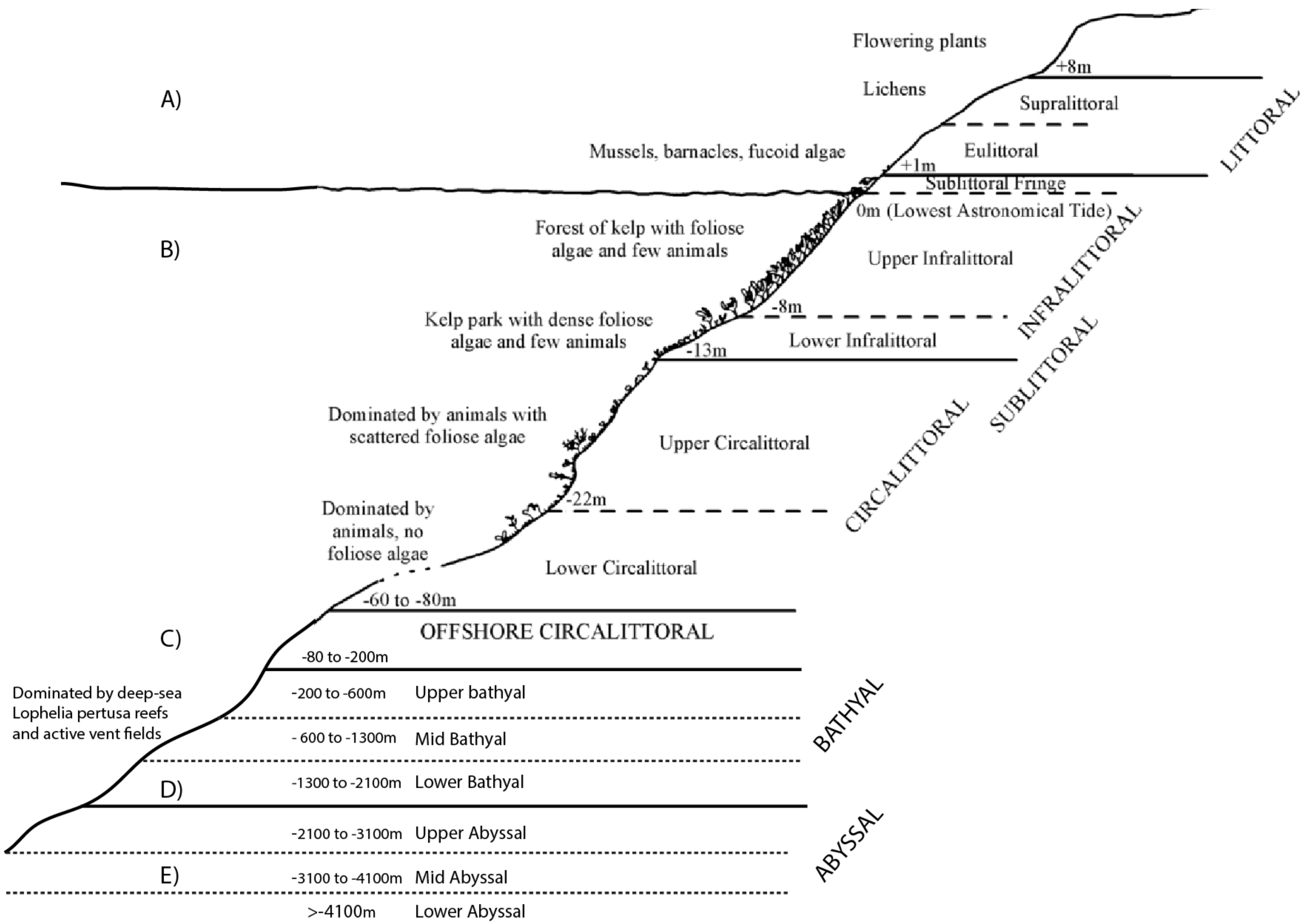

Figure 31. The schematic representation was based on the Biozone classification offered by EMODnet (2018), Connor et al. (2004:24) and Parry et al. (2015:12).

Biological zone	**Habitat descriptor class boundary**	**Immersion**	**Thermal Stability**	**Depth**	**Light**	**Salinity**[215]	**Wave Action**
Littoral: (splash zone, strandline and intertidal)	Supralittoral	Spay and splash	Highly variable	(+10 to +6m)	Photic[216] (NOAA 2018c)	Saline influence	None
	Eulittoral:	Regular inmersion and emersion		(+7 to 6+m)		Euryhaline[217]	
	Sublittoral Fringe	Springtide emersion		(0 to 1m)			Highly variable Highly variable

[215] Salinity - The categories are defined as follows (the points of separation approximate to critical tolerance limits for marine species): Fully marine (30-40%), Variable (18-40%), Reduced (18-30 %) and Low (<18 %) (Connor 2004:45).
[216] The Photic or Euphotic zone is the top layer, nearest the surface of the ocean and is called the sunlight layer. In this zone, enough light penetrates the water to allow photosynthesis (NOAA 2018).
[217] Plants and animals that can tolerate a wide range of salinities are called euryhaline. These are the plants and animals most often found in the brackish waters of estuaries (NOAAd)

Biological zone	Habitat descriptor class boundary	Immersion	Thermal Stability	Depth	Light	Salinity[215]	Wave Action
Sublittoral: (shallow subtidal)	Upper Infralittoral	Immersed	Variable Eurythermal	(0m to - 8m)	Euphotic	Mesohaline/ Stenohaline [218]	
	Lower Infralittoral		Modrately variable- mesothermal	(-8m to -13m)			
	Upper Circalittoral			(-13m to -22m)	Mesophotic [219] (NOAA 2018d)		Moderately variable
	Lower Circalittoral		Modrately variable- mesothermal	(-22 to -80m)			Stable

[218] Stenohaline, this area has very low range of salinities.
[219] "Meso" means middle and "photic" refers to light, this level with lower light that shallow waters gradually moves into the no light zone (Aphonic) (NOAAc).

Biological zone	Habitat descriptor class boundary	Immersion	Thermal Stability	Depth	Light	Salinity[215]	Wave Action
Offshore Circalittoral		Immersed	Stable steno-thermal[220]	(-80m to -200m)	Aphotic[221] (NOAA 2018c)	Stenohaline	
Bathyal	Upper Bathyal		Very stable stenothermal	(-200 to -600m)			
	Mid Bathyal			(-600 to -1300m)			
	Lower Bathyal			(-1300 to -2200m)			
Abyssal	Upper Abyssal			(-2200 to -3200m)			
	Mid Abyssal	Immersed		(3200 to -4300m)			

220 Stenothermal, this area has very low range of changes in temperature.
221 The darkness layer or Aphotic Zone is entirely dark meaning there is no light (NOAA 2018b).

Biological zone	Habitat descriptor class boundary	Immersion	Thermal Stability	Depth	Light	Salinity[215]	Wave Action
Abyssal	Lower Abyssal			(>-4300m)			

Table 15. The tables explain the habitats' descriptor class, variables and threshold used to classify each Biozone according to EMODnet (Connor et al. 2004:25; EMODnet 2018; JNCC 2018)**.**

4.2.4 Substratum

The substratum classification system used for this thesis is based on the Folk triangle used by the BGS (Long 2006:3, 5) (Figure 32). The seabed substratum is a critical factor for the site formation process of a shipwreck, as it will determine if the wrecks' remaining structure is covered by gravel[222], sand[223] or mud[224] and a combination of these to different percentages (Figure 32). The natural processes (physical, chemical and biological) that affect the shipwrecks' state or preservation are highly determined by the energy in relation to the substratum composition. Therefore, having a comparative system of seabed substratum is critical to characterise the marine environment.

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222 As shown in this chapter rocky and gravel substratums will affect the physical erosion process of the shipwrecks remains (This is the case for most protected wrecks on the Cornish coast including the Scilly Isles).

223 *Invincible* presents a good case study with the preservation of a large part of the structure because it was buried by a sand bank (See Chapter VII). However, the coarse nature of sand in high-energy environments also act as an important source of physical erosion. *Rooswijk* also presents high-energy environments with mobile sands (Chapter VI).

224 To mentions an example, a wreck that lies in Mud, silts and clay will have an advantage of creating anoxic environments that will slow down the biological decay, such was the case of the Mary Rose (Marsden 2003; Quinn, et al. 1997).

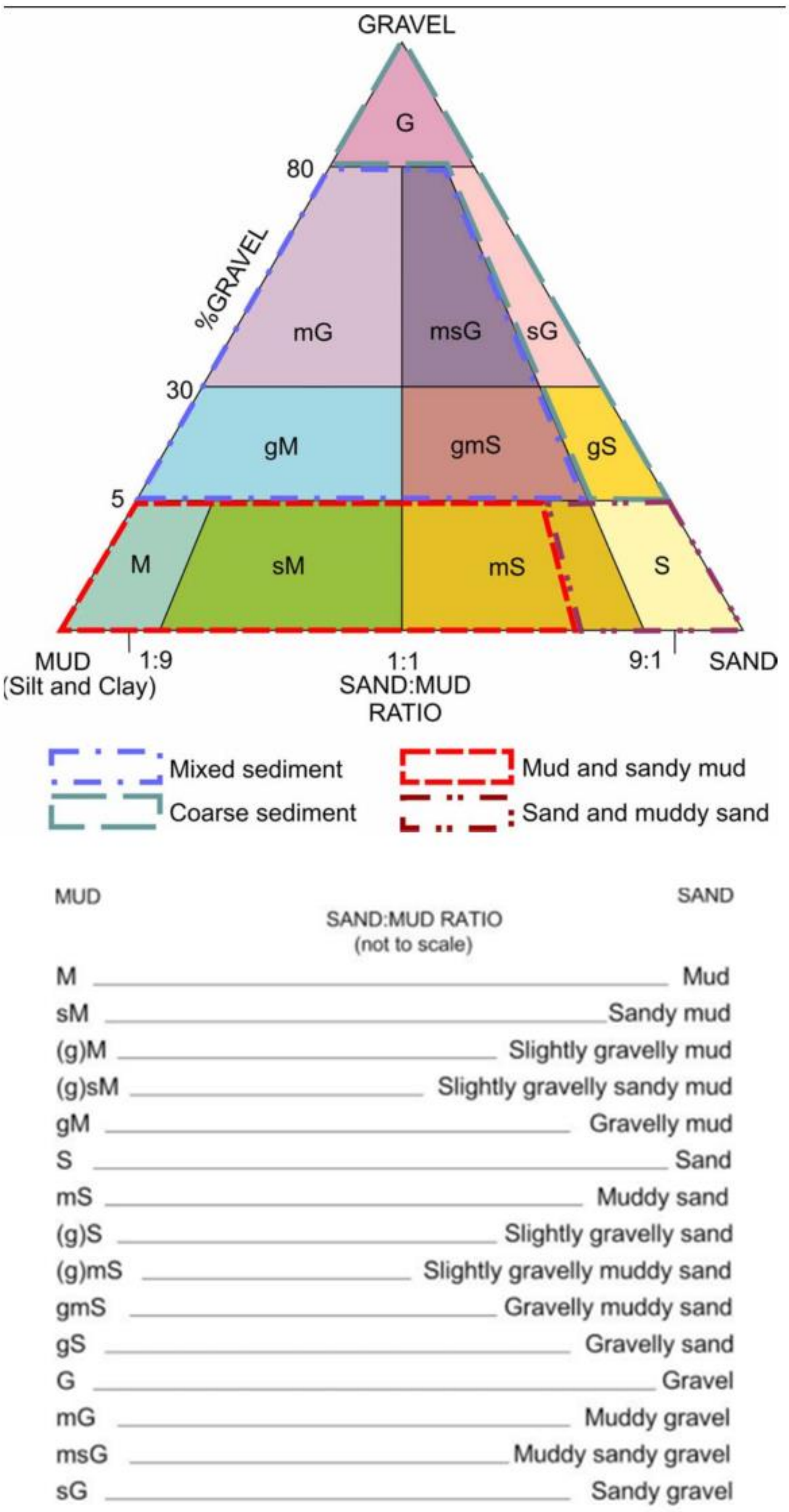

Figure 32. Reclassification of the Folk triangle for UKSeaMap according to the BGS (Long 2006:3, 5)**. The image was created by the author of this thesis based on two figures used to explain the seabed classification for BGS.**

4.2.5 Energy

The environment energy is determined by wave action, exposure-sea horizon (fetch) and tidal strength as explained in the previous sections, creating subcategories related to the seabed substratum.

Habitat description	Habitat descriptor class boundary	Variable(s)	Waves (Nm^2)	Tides (Nm^2)
Energy	High Energy	Wave exposed or very tides swept	>1.2	>1.16
	Moderate Energy	Moderatly wave exposed or tide swept	0.21 – 1.2	0.13-1.16
	Low Energy	Wave sheltered and weak tidal currents	<0.21	<0.13

Table 16. The table shoes EMODnet categories the criteria followed by this thesis for energy classification (Connor et al. 2004:22, 2006; EMODnet 2016:137–38, 2018; McBreen et al. 2011:23–26; Populus et al. 2017) **2016:137–38, 2018).**

4.3 A Typology of Wrecks and their Environments

The extensive work on shipwrecks in British waters has produced a vast amount of information and databases with a great variety of sites. This poses an obvious challenge for the classification of sites and their management. It is essential, if not more realistic, to prioritise historically significant or rare examples of shipwrecks to guarantee their legal protection and that they have resources to be investigated, preserved and monitored. This is afforded by the designation of a Protected Wreck status, which considers environmental, economic resources, social impact and future marine spatial planning. Within the current list of Protected Wrecks, there are a few that are classified as At Risk [225] and have a priority status regarding resources and organisation (*Invincible, London, Northumberland* and *Rooswijk*). Historic England considers the

[225] See section 4.2.4

assessment of three main factors: condition[226], vulnerability[227] and trajectory[228] (HE 2017b)[229].

This section presents an innovative evaluation of the marine environment energy levels (high, moderate or low) in relation to the degree of impact on the wrecks structural remains, the presence of artefacts and their distribution. Expanding or enhancing the four principal attributes: visibility, fabric condition, fabric condition trend and fabric vulnerability presented by HE (2017a:13).

The main aim of this thesis is to present better archaeological results that will aid better strategies for cultural heritage care. It is argued throughout this thesis that the resolution and quality of data has a direct impact on the evaluation of the impact of the environment on the wreck. Unfortunately, Muckelroy did not have such resources available when he wrote his groundbreaking chapter on *the archaeology of shipwrecks* (Muckelroy 1978a:157–214). Muckelroy's limitations were determined by the technology available in the late seventies, restricting the possibilities of fully integrating macro-scale, and mesoscale modelling with intra-site and *in situ* observations.

It is within the remit of this thesis to produce a macro-scale classification of shipwrecks in British waters based on their environment and archaeological record. However, this is limited to the Protected Wreck Sites of England, and it is worthy of further research by integrating more wrecks registered by the UKHO, as well as the Protected Wrecks in Wales, Scotland, Northern Ireland and British Overseas Territories. This could be led by an environmental characterisation and the impact on sites by regions with High, Moderate or Low energy levels.

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226 The current condition of the wreck, whether in optimal condition, generally satisfactory, generally unsatisfactory or having extensive problems.

227 An assessment of the natural and anthropogenic influences on the site

228 An assessment of the management regime and whether the monument condition is improving, remaining stable or experiencing unmanaged or inappropriate decline.

229 Further discussed in the previous section 4.2.4

Muckelroy proposed a five-class shipwreck typology, based on the available archaeological record[230], according to their degree of survival (Muckelroy 1978a:164) (Table 17). The classes ranged from extensive structural remains, with many objects and a coherent distribution, or Class 1, to no structural remains, with few objects in a scattered distribution or Class 5 (Table 17).

Class	**Structural remains**	**Organic remains**	**Other objects**	**Distributions**	**Examples**
1	Extensive	Many	Many	Coherent	*Mary Rose* *The Anne* *Amsterdam*
2	Elements	Some	Many	Scattered ordered	*Dartmouth* *Trinidad V.*
3	Fragments				*Kennemerland* *Colossus*
4	-	Few	Some	Scattered / disordered	*De Liefde* *Girona*
5	-	-	Few		*Adelaar* *Penlee Site*

Table 17 Site classification according to Muckelroy (Muckelroy 1977:48–50, 1978a:164)

Muckelroy's (1978a:168) main contribution was to analyse environmental attributes (topography, deposits, slope, sea horizon and fetch), in relation to the impact these had on the site formation process of a wreck (Table 18).

However, Muckelroy limited his study to twenty wrecks, considering the sites with enough information to catalogue and forty years ago, he did not have the means or data resolution to measure these attributes of the marine environment[231].

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[230] Muckelroy's classification included only ten wrecks, of nineteen possible case studies in the UK.

[231] Further explained in Chapter III

Class	Topography % of bottom sedimentary deposit	Deposit range of sediments	Slope average over the whole site	Sea horizon sector of open water for 10+KM	Fetch Maximum offshore distance
1	100%	Gravel to Silt	Minimal	>90°	>250km
2	More than 70%	Boulders to silt	> 2°	>90°	>250km
3	More than 30%	Boulders to silt	>4°	>150°	<250km
4	More than 10%	Boulders to sand	>8°	<30°	<250km
5	Less than 25%	Boulders to gravel	<6°	<120°	<750km

Table 18. Environmental attributes for each of the five classes of wreck site derived from 20 British sites (Muckelroy 1978a:164).

This macro-scale approach presents the marine in relation to the 53 listed Protected Wrecks of England. The environmental dynamics or energy levels were classified using the available data sets for the UK[232]. The archaeological record, structural integrity, the distribution pattern of the wrecks and/or the associated artefacts[233], were obtained by extracting information from the available publications, books, grey literature (archaeological assessment reports), websites and fieldwork.

To facilitate the description of the shipwreck classification the attributes were divided between A) natural factors and B) cultural factors.

A) The natural factors that compose the marine environment (Table 15):

[232] See section 4.1 on marine environment. The full list of protected wreck in UK including Scotland, Wales and Northern Ireland in Appendix I. section 1.2.
[233] Further explained in Chapter II, section 2.2 site formation processes on shipwrecks.

- Energy[234]
    - Seabed sediment or substratum[235]
    - Distance to shore
    - Depth
    - Biozone

B) The state of preservation[236] of the wrecks is measured in structural integrity, the presence or absence of artefacts and their distribution on the seabed as follows:

- Structure (class)
    - Extensive
    - Elements
    - No structure
- Distribution (sub-class)
    - Scattered ordered
    - Scattered discorded
- Objects/Artefacts (sub-class)
    - Many
    - Some
    - Few

The chart (Table 19) presents the 53 Protected Wrecks, classified under the state of preservation categories (B)[237] and their associated environmental attribute (A). Each of the environmental attributes (A) has a differentiated impact on a wreck site and this is why they were presented separately (Table 20, Table 21 and Table 22).
The energy category compiles all of the environmental attributes and their relation to the classes and sub-classes of the state of preservation of the wrecks are presented in Table 19.

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234 This includes, topography, slope, sea horizon, wave exposure, proximity to the coast, fetch, depth, and tidal currents. See section 4.1.5 and recording field 19 of table 15 in section 4.2.4 to compare.
235 See section 4.1.4 and recording field 18 of table 15 in section 4.2.4
236 What HE considered as fabric
237 Structural remains (extensive, elements or no structure), Distribution (coherent, scattered ordered or scattered disordered) and number of artefacts or objects (many, some or few).

It is important to recognise that the archaeological record is biased by the selection of only Protected Wrecks. Additionally, the archaeological record relies on the accuracy of each publication, report or assessment. These publications were also carried out to different standards and at different times. However, this is a normal bias in the archaeological record for any macro-scale study that integrates a wide range of sources. Most importantly, this does not contemplate all cultural factors such as salvage (contemporary to the wrecking or modern), archaeological excavations, or other human activities at sea that could affect the wreck. Therefore, it is important not to jump to conclusions and explain that the reason why there are more wrecks in high-energy environments is that these would be perilous waters to navigate.

The analysis of the state of preservation of the Protected Wrecks in relation to the environmental energy presents a differentiated pattern between high, moderate and low energy (Figure 34):

C)

- High energy[238] 25/53 (TP 47.16%)
    - Low rate of extensive remains 4/25 or 16% (TP 7.54%)
    - Low rate of coherent wrecks 5/25 or 20% (TP 9.43%)
    - Low rate of scattered ordered 4/25 or 16% (TP 7.54%)
    - Low rate with many artefacts or objects 5/25 or 20% (TP 9.43%)
    - High rate of scattered disordered 16/25, or 62% (TP 30.18%)

- Moderate energy 21/53 (TP 39.62%)
    - High rate of extensive remains 11/21 or 52.38 % (TP 20.75%)
    - High rate of elements 8/21 or 38.09% (TP 15.09%)
    - Low rate of no structure 2/21 or 9.52% (TP 3.77%)
    - Low rate of scattered ordered 3/21 or 14.28% (TP 5.66%)
    - High rate of few artefacts or objects 9/21 or 42.85% (16.98%)

- Low energy 7 / 53 (TP 13.2%)

[238] The percentage where calculated for each category (high, moderate or low), as well as the total percentage (TP) in relation to the total number of Protected Wrecks.

- High rate of extensive remains 4/7 or 57.1428 % (TP 7.54%)
- High rate of coherent wrecks 4/7 or 57.1428 % (TP 7.54%)

TP represents the full complexity of the three main energy levels (high, moderate and low) in relation to the structural remains, it was necessary to create classes and sub-classes as follows (Figure 34 and Figure 35):

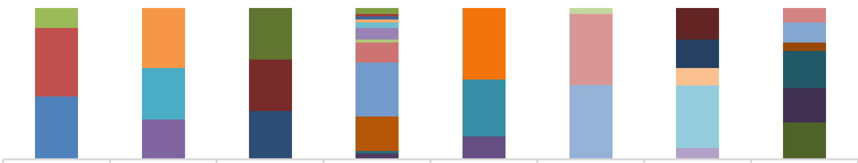
- High energy (H)[239]
  - Structural remains (class)
    - Extensive (H1)
      - Distribution (sub-class)
        - Coherent (H1a)
          - Artefacts or objects (sub-class)
            - Many (H1aM)
            - Some (H1aS)
            - Few (H1aF)
        - Scattered ordered (H1b)
          - Artefacts or objects (sub-class)
            - Many (H1bM)
            - Some (H1bS)
            - Few (H1bF)
        - Scattered disordered (H1c)
          - Artefacts or objects (sub-class)
            - Many (H1cM)
            - Some (H1cS)
            - Few (H1cF)
  - Structural remains (class)
    - Elements (H2)
      - Distribution (sub-class)
        - Coherent (H2a)
          - Artefacts or objects (sub-class)

[239] The same system of class and sub-classes is followed for moderate and low energy categories.

- Many (H2aM)
- Some (H2aS)
- Few (H2aF)

- Scattered ordered (H2b)
  - Artefacts or objects (sub-class)
    - Many (H2bM)
    - Some (H2bS)
    - Few (H2bF)
- Scattered disordered (H2c)
  - Artefacts or objects (sub-class)
    - Many (H2cM)
    - Some (H2cS)
    - Few (H2cF)

- Structural remains (class)
  - No Structure (H3)
    - Distribution (sub-class)
      - Coherent (H3a)
        - Artefacts or objects (sub-class)
          - Many (H3aM)
          - Some (H3aS)
          - Few (H3aF)
      - Scattered ordered (H3b)
        - Artefacts or objects (sub-class)
          - Many (H3bM)
          - Some (H3bS)
          - Few (H3bF)
      - Scattered disordered (H3c)
        - Artefacts or objects (sub-class)
          - Many (H3cM)
          - Some (H3cS)
          - Few (H3cF)



	Distribution	Objects	Structure	Seabed Substratum	Energy	Biozone	Distance to shore	Depth
<26m								5
21-25m								7
16-20m								3
11-15m								13
6-10m								12
0-5m								13
<5km							11	
1-5km							10	
.5-1km							6	
>500m							22	
0							4	
Lower Circalittoral						2		
Upper Circattoral						25		
Infralittoral						26		
High					25			
Medium					20			
Low					8			
msG				2				
(g)M				1				
gM2				1				
mS				1				
M				2				
(g)S				4				
sM				1				
sG				7				
gS				19				
S				12				
G				1				
gM				2				
No Structure			18					
Elements			18					
Extensive			17					
Few		21						
Some		18						
Many		14						
Scattered Ordered	7							
Scattered Disordered	24							
Coherent	22							

Table 19. A distribution based on 53 Protected Wrecks sites and their environmental classification. M Mud, sM Sandy mud, (g)M Slightly gravelly mud, (g)sM Slightly gravelly mud, gM Gravelly mud, S Sand, mS Muddy Sand, (g)S Slightly gravelly sand, (g)mS Slightly gravelly muddy sand, gmS Gravelley muddy sand, gS Gravelly sand, G Gravel, mG Muddy gravel, msG Muddy sandy gravel and sG Sandy gravel (Long 2006).

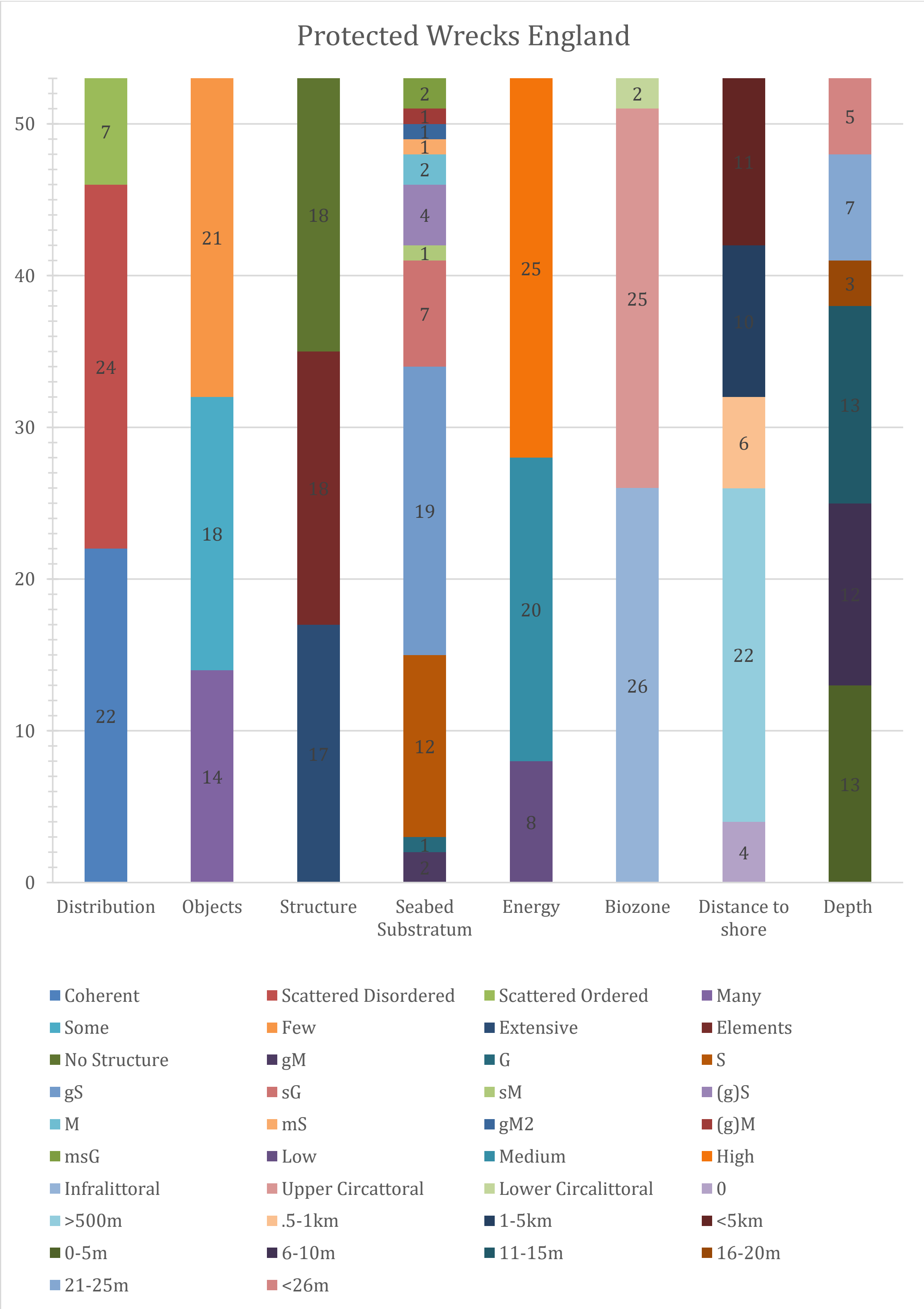
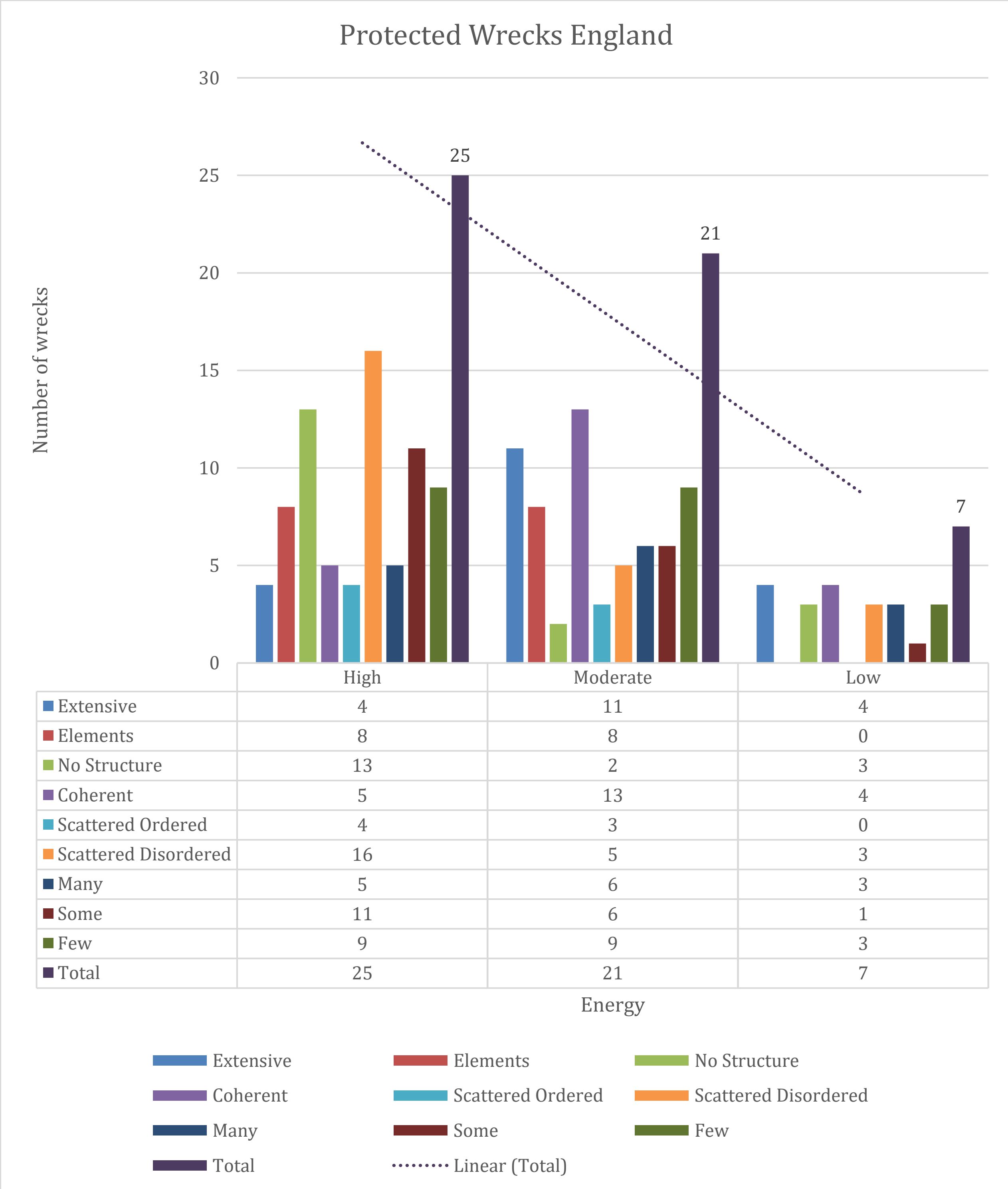


Figure 33. A distribution based on 53 Protected Wrecks sites and their environmental classification. M Mud, sM Sandy mud, (g)M Slightly gravelly mud, (g)sM Slightly gravelly mud, gM Gravelly mud, S Sand, mS Muddy Sand, (g)S Slightly gravelly sand, (g)mS Slightly gravelly muddy sand, gmS Gravelley muddy sand, gS Gravelly sand, G Gravel, mG Muddy gravel, msG Muddy sandy gravel and sG Sandy gravel (Long 2006)**.**



	High	Moderate	Low
Extensive	4	11	4
Elements	8	8	0
No Structure	13	2	3
Coherent	5	13	4
Scattered Ordered	4	3	0
Scattered Disordered	16	5	3
Many	5	6	3
Some	11	6	1
Few	9	9	3
Total	25	21	7

Figure 34. The charts show three groups of High, Moderate and Low energy environments and the Protected Wreck sites structural integrity as well as their distribution

High Energy			
Structural remains (Class)	**Distributions (Sub-class)**	**Objects / Artefacts**	**Examples**
Extensive (H1)	Coherent (H1a)		
	(H1aM)	Many	***Admiral Gardner*** (PAS 2017; Wessex Archaeology 2013a) ***Stirling Castle*** (Astley 2016; PAS 2017; Wessex Archaeology 2003b) ***HMS/m A1*** (Wessex Archaeology 2006b)
	(H1aS)	Some	***Seaton Carew*** (OESEA3 2014:715; Satchell and Whitewright 2014:23; Whitewright and Satchell 2015:39)
	(H1aF)	Few	
	Scattered Ordered (H1b)		
	(H1bM)	Many	
	(H1bS)	Some	
	(H1bF)	Few	
	Scattered Disordered (H1c)		
	(H1cM)	Many	
	(H1cS)	Some	
	(H1cF)	Few	
Elements (H2)	Coherent (H2a)		
	(H2aM)	Many	
	(H2aS)	Some	***Hazardous*** (Johnston 2014; Owen 1991; WHPPG 2018b)
	(H2aF)	Few	
	Scattered Ordered (H2b)		
	(H2bM)	Many	
	(H2bS)	Some	***Association*** (CISMAS 2018a; Morris 1969) ***Hanover*** (Dresch and Evans 2017; Parham, Underwood, and Brown 2013)
	(H2bF)	Few	
	Scattered Disordered (H2c)		
	(H2cM)	Many	
	(H2cS)	Some	***Tearing Ledge*** (Camidge and Johns 2017; CISMAS 2017; Wessex Archaeology 2008)

			The Needles Site (Satchell and Whitewright 2014; Tomalin et al. 2000) ***Norman's Bay Wreck*** (Beattie-Edwards 2017; Beattie-Edwards, Le Fevre, and Fox 2017)
	(H2cF)	Few	***Dunwich Bank*** (Wessex Archaeology 2006a)
No Structure (H3)	Coherent (H3a)		
	(H3aM)	Many	
	(H3aS)	Some	
	(H3aF)	Few	
	Scattered Ordered (H3b)		
	(H3bM)	Many	***Rooswijk* (chapter VI)***
	(H3bS)	Some	***Schiedam Prize*** (Camidge 2013b)
	(H3bF)	Few	***Rill Cove*** (Camidge 2008, 2013a)
	Scattered Disordered (H3c)		
	(H3cM)	Many	
	(H3cS)	Some	***St Anthony*** (Camidge 2007, 2013c; Wessex Archaeology 2007) ***Royal Anne*** (Camidge and Johns 2014, 2016b) ***Coronation Inshore*** (Wessex Archaeology 2004a) ***Loe Bar Wreck*** (Wessex Archaeology 2005c)
	(H3cF)	Few	***Moor Sand*** (Tyson and Palmer 2013) ***Bartholomew Ledges*** (Camidge and Johns 2016a; Wessex Archaeology 2005a) ***Erme Estuary*** (Oldham, Palmer, and Tyson 1993) ***Salcombe Cannon Site***(Wessex Archaeology 2006d) ***West Bay*** (Wessex Archaeology 2018) ***Coronation Offshore*** (Berry and Camidge 2012; Holt 1997; MAST 2017; Wessex Archaeology 2004a) ***Chesil Beach Cannon Site***

Table 20. High energy environment classification based on EMODnet (EMODnet 2018) and the author of this thesis research on the Protected Wreck Sites.

Moderate Energy			
Structural remains	**Distributions**	**Objects / Artefacts**	**Examples**
Extensive (M1)	Coherent (M1a)		
	(M1aM)	Many	***Northumberland*** (PAS 2017:10, 22; Pascoe, Mavrogordato, and Middleton 2014; Pascoe and Peacock 2015) ***Restoration*** (PAS 2017:14, 26; Pascoe and Peacock 2015; Wessex Archaeology 2006c) ***London*** (Artas Media 2018; PAS 2018b) ***Studland Bay Wreck*** (Parham 2005; Thomsen and Jarvis 2000) **(In transition)** ***HMS Invincible*** (Bingeman 2010; PAS 2015; PAS and Artas Media 2018; Pascoe and Cowan 2017)
	(M1aS)	Some	***Holland No.5*** (Beattie-Edwards 2014; NAS & 3Deep n.d.; Wessex Archaeology 2009) ***SM U-8*** (MSDS Marine Ltd & Artas Media 2018b)
	(M1aF)	Few	***HM Submarine A3***(Cotswold Archaeology Marine 2014:32, 40, 50) ***HMT Arfon*** (MAT & Artas Media 2018; MAT 2018) ***SM UC-70*** (Wessex Archaeology 2017) ***Iona II*** (Daykin-iliopoulos and Cousins 2013; Wessex Archaeology 2004c, 2005b)
	Scattered Ordered (M1b)		
	(M1bM)	Many	
	(M1bS)	Some	
	(M1bF)	Few	
	Scattered Disordered (M1c)		
	(M1cM)	Many	
	(M1cS)	Some	
	(M1cF)	Few	
Elements (M2)	Coherent (M2a)		
	(M2aM)	Many	***Rooswijk*** (MSDS Marine Ltd 2018; PAS 2017:7, 20; WA 2007)*
	(M2aS)	Some	
	(M2aF)	Few	***GAD8*** (PAS 2017:14,28; Wessex Archaeology 2011b) ***Thorness Bay Wreck*** (Wessex Archaeology 2011a)

	Scattered Ordered (M2b)		
	(M2bM)	Many	
	(M2bS)	Some	
	(M2bF)	Few	
	Scattered Disordered (M2c)		
	(M2cM)	Many	***Swash Channel Wreck*** (Nayling 2010; Palma and Parham 2007; Parham 2011)
	(M2cS)	Some	
	(M2cF)	Few	***Cattewater*** (Holt 2010; Redknap 1997; Report 2011) ***Filey Bay Wreck*** (Wessex Archaeology 2003a)
No Structure (M3)	Coherent (M3a)		
	(M3aM)	Many	
	(M3aS)	Some	
	(M3aF)	Few	
	Scattered Ordered (M3b)		
	(M3bM)	Many	
	(M3bS)	Some	
	(M3bF)	Few	
	Scattered Disordered (M3c)		
	(M3cM)	Many	
	(M3cS)	Some	***Wheel Wreck*** (CISMAS 2018b)
	(M3cF)	Few	***Gull Rock*** (Daykin-iliopoulos and Cousins 2013; Wessex 2009)

Table 21. Moderate energy Environment classification based on EMODnet (EMODnet 2018) and the author of this thesis research on the Protected Wreck Sites.

Low Energy			
Structural remains	**Distributions**	**Objects / Artefacts**	**Examples**
Extensive (L1)	Coherent (L1a)		
	(L1aM)	Many	**Amsterdam** (Gawronski 1990; Marsden 1974, 2007) **Anne** (Marsden and Lyon 1977; Martin 2008) **Mary Rose** (Hocker 2010; Marsden 2003; Mary Rose Museum 2018; Quinn, Bull, and Dix 1997)
	(L1aS)	Some	
	(L1aF)	Few	**Grace Dieu and the possible site of Holigost** (Friel 1993; Plets et al. 2009)
	Scattered Ordered (L1b)		
	(L1bM)	Many	
	(L1bS)	Some	
	(L1bF)	Few	
	Scattered Disordered (L1c)		
	(L1cM)	Many	
	(L1cS)	Some	
	(L1cF)	Few	
Elements (L2)	Coherent (L2a)		
	(L2aM)	Many	
	(L2aS)	Some	
	(L2aF)	Few	
	Scattered Ordered (L2b)		
	(L2bM)	Many	
	(L2bS)	Some	
	(L2bF)	Few	
	Scattered Disordered (L2c)		
	(L2cM)	Many	
	(L2cS)	Some	
	(L2cF)	Few	
No Structure (L3)	Coherent (L3a)		
	(L3aM)	Many	
	(L3aS)	Some	
	(L3aF)	Few	
	Scattered Ordered		

	(L3b)		
	(L3bM)	Many	
	(L3bS)	Some	
	(L3bF)	Few	
	Scattered Disordered (L3c)		
	(L3cM)	Many	
	(L3cS)	Some	**Church Rocks** (Preece 2004)
	(L3cF)	Few	**Erme Ingot** (Loughman 2007) **Langdon Bay** (Needham, Parham, and Frieman 2013)

Table 22. Low energy Environment classification based on EMODnet (EMODnet 2018) and the author of this thesis research on the Protected Wreck Sites.

4.4 Conclusions

The critical analysis of shipwreck classification systems by period, craft type, legal status and sites at risk, brings to light the complexity of UCH. This analysis revealed that differentiating between *n-factors* and *c-factors* can be reductive, but it also represents a useful analytical tool for comparative studies between wrecks and environment. The shipwreck site classification presented in this chapter highlights the dynamic nature of UCH and the limitations of typologies only based on environmental or cultural differences. The integrated methodology used in this thesis encompasses both *n-factors* and *c-factors*, making it possible to classify marine environments, their types and their impact on Protected Wrecks sites.

The deconstruction of marine environments (wave exposure, sea horizon, tidal currents, biozones, substratum and energy) allows identifying risk factors that affect the UCH. This macro-scale research model on shipwrecks presents an innovative method to understand site formation processes and it could have an impact on current site management policies in the UK (eg. (HE 2017a, 2019b)).

The aim of this thesis is to present better archaeological results that enable better-informed strategies for heritage care. The key contribution of this chapter is presenting a macro-level analysis using the energy level (high, moderate or low) as the main environmental attribute used to classify the marine environment. The meso and intra-site scale assessments of the Protected Wrecks were compiled under the state of preservation attribute. The use of classes (structural remains) and sub-classes (distribution and artefact quantity) provides further insight into each shipwreck. The integrated shipwreck and environmental classification of the Protected Wrecks (Table 20, Table 21 and Table 22), presents this complex relationship.

The dynamic marine environments are continuously changing, and this affects the UCH. Therefore, to provide an accurate risk assessment of historically significant vessels, based on the archaeological record a continuous monitoring programme is necessary with at least an annual assessment. The implementation of integrated methodologies such as the one presented in this thesis will have better informed cultural heritage care strategies than only estimating if the environment is of high, moderate or low energy.

4.4.1 Further research

If a macro-scale assessment included the estimated 60,000 wrecks around the UK (Cant 2013) and analysed their distribution in relation to the environmental energy, this could provide a better correlation. Despite this, the information for the estimated 60,000 wrecks would not be as extensive as the one found for the Protected Wrecks. However, this goes beyond the scope of this thesis, as it is a monumental task. By presenting this macro-scale approach with a robust methodology it is possible to have a general overview of the situation of wrecks in British waters. Moreover, this could be carried out in any other part of the world where there is available data[240]. Creating lesser resolution proxies for a general evaluation of UCH, their environmental dynamics and the impact on the structural remains.

However, when there are available datasets then the high-resolution studies will provide better interpretations of sites. Many wrecks sites have previous studies that require re-interpretation with the aid of new technologies such as the case studies presented on this thesis.

[240] EMODnet data is available in Europe and other parts of the world, including the Atlantic, North Sea, Norwegian Sea, Barents Sea, Baltic Sea, Mediterranean, Black Sea, and Red Sea (Submerged landscape feature released in 2019 (EMODnet 2019)).

Chapter V. *Hazardous Prize* 1699-1706 in Bracklesham Bay, *West* Sussex

This chapter aims to re-visit the *Hazardous* wreck site presenting an integrated methodology that includes over 30-years of previous work on site and the most recent multi-image photogrammetric surveys. The re-interpretation of the site formation processes of the *Hazardous,* presented in this chapter was based on macro-scale surveys and recent *in situ* intra-site observations.

5.1 Historical Background

The *Hazardous* was built in 1699[241] by *La Royale*[242] in the shipyard of Lorient near to Port Louis, France, where she was originally known as *Le Hazardeux*. The prestigious boat builder François Coulomb[243], part of a highly recognised family in the trade, designed her as a 50-gun ship of the line (Holland 2015:13; WHPPG 2018b; Winfield 1997:125). The vessel was swiftly built, laying down her keel in March 1699 and launched shortly after in August of that same year (Figure 39).

The *Ministère de la Marine*[244] records show *le Hazardeux* had a length of 128 ft[245] (41.58 m), a beam of 35.5 feet (11.53m), a draught of 14 feet (4.55m) with a displacement of 726 tonnes (Historica Canada 2018; WHPPG 2018b).

(2017b)[241] Dates given below are Julian or Old Style calendar as that was the system used in England up until 1752.

[242] *La Marine Nationale* or *La Royal* is the maritime arm of the French Armed Forces dating back to 1624.

[243] Laurent Coulomb (1622-1696) was the founder of the family, followed by three sons: Antoine Coulomb (?-1702), François Coulomb (1654-1717), and Blaise Coulomb (1665-1741). François Coulomb the elder was the designer of *Hazardous* in 1699. Two of his sons continued the trade François Coulomb the younger (1691-1751) and Honoré Coulomb (1700-1730). Blaise Coulomb also had three sons that where in the trade: Pierre Blasie Coulomb (1699-1753), Joseph Coulomb (1704-1728) and Jacques Lue Coulomb (1713-1791). There was third generation: Coulomb Claude Louis Coulomb (1725-1748) and François Coulomb (1729-1751), sons of François Coulomb the younger. As well as, Joseph Marie Blaise Coulomb (1728-1803), son of Joseph Coulomb (See Appendix II, B *Hazardous,* for family tree).

[244] The Ministère de la Marine was a section of the French government, apart from the Ministry of War, that was in charge of the French navy and colonies.

[245] 1 Foot (French measure or Paris foot) = 12.789 inches) or

She was armed with twenty-two 18pdrs[246] on the Lower Deck, (LD)[247], twenty-two 12pdrs on the Upper-deck (UD)[248], and six 6pdrs on the Quarterdeck (QD)[249] (Owen 1988:285, 1991:285; WHPPG 2018b; Winfield 2010:144, 2014; Winfield and Roberts 2017). The *Hazardous* was catalogued as a French Third-rate[250], being manned by a crew of 350 with seven officers, even though this vessel was larger than the average English Fourth Rate of the time carrying up to 60 guns.

The *Hazardous* was built during Louis XIV's reign, also known as the "Sun King" hence the sun carved into the stern (Figure 35 and Figure 36). This period was marked by the French Wars in Europe 1674-1714 (Lavery 2014:28), during which the French Navy had consolidated itself as a great maritime power. This period was noticeable for the effort to standardise shipbuilding techniques between the different shipyards, as well as the creation of a consistent rate-classification.

Le Hazardeux had a relatively short career under the French flag. She served six years mainly as a privateer for several Atlantic crossings. In 1703, the French Royal Navy loaned Le Hazardeux to a shipowner and privateer named De Beaubriand.

While navigating in the Channel, The *Orford*, *Warspite* and *Lichfield*, captured her on 2nd November 1703. She had to be towed into Portsmouth Harbour as a war prize after some serious damage inflicted to her overall structure. During the following six months, the ship was extensively rebuilt and re-gunned*. Hazardous Prize*[251] was commissioned into the English Royal Navy on 27th March 1704, as a Fourth-rate with

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[246] Pdrs, abbreviation for pounders, refereeing to the weight of the shot fired with the gun.
[247] LD refers to the Lower Deck, although it also is an acronym for Long-Distance (Winfeld 2014 XVI).
[248] UD Upper-Deck, MD is Main-Deck
[249] QD refers to Quarterdeck. Although the acronym also stands for quick-detach meant to allow the sling swivels to be easily detached if the need arises.
[250] After 1715, the French Navy classified their ships: First-rate 80-guns or more, Second-rate 68-78 guns, Third-rate 56-66 guns, Forth-rate 40-55 guns, or Frigates of first order, Fifth-rate Frigates of second order. In addition, minor warships, barques, brigantines, tartans, feluccas, xebecs, light frigates, bomb-vessels, gunboats (*Chaloupes-canonnieres*) corvettes, schooners, etc.

[251] The 1677 building programme led by Samuel Pepys started to standardise shipbuilding within England.

a crew of 320 men, 54 guns[252], and with an increased displacement of 875 tons (Owen 1988; WHPPG 2018b).

Unfortunately, there are no original plans for *Hazardous*. However, the prolific Coulomb family built several *Assuré Class* ships in the same yard of Lorient. The *Assuré* (1697-1712)[253], *Sage* 55-guns (1701-1702), *Oriflamme* 60-gun (1699-1698), *Rubis* 56-gun and *Le Superbe* 56-gun (1708-1732) (Winfield 2014:117–18; Winfield and Roberts 2017:130–38) (Fig. 39). In 1710, the British Navy also captured *le Superbe*, which was taken as a prize and commissioned as the *Superb*. This ship was surveyed and the plans are held at the National Maritime Museum (Uknown n.d.) (Figure 38).

[252] A combination of French amd English guns.
[253] She was captured by the British Navy in 1702 and re-named *Assurance.*

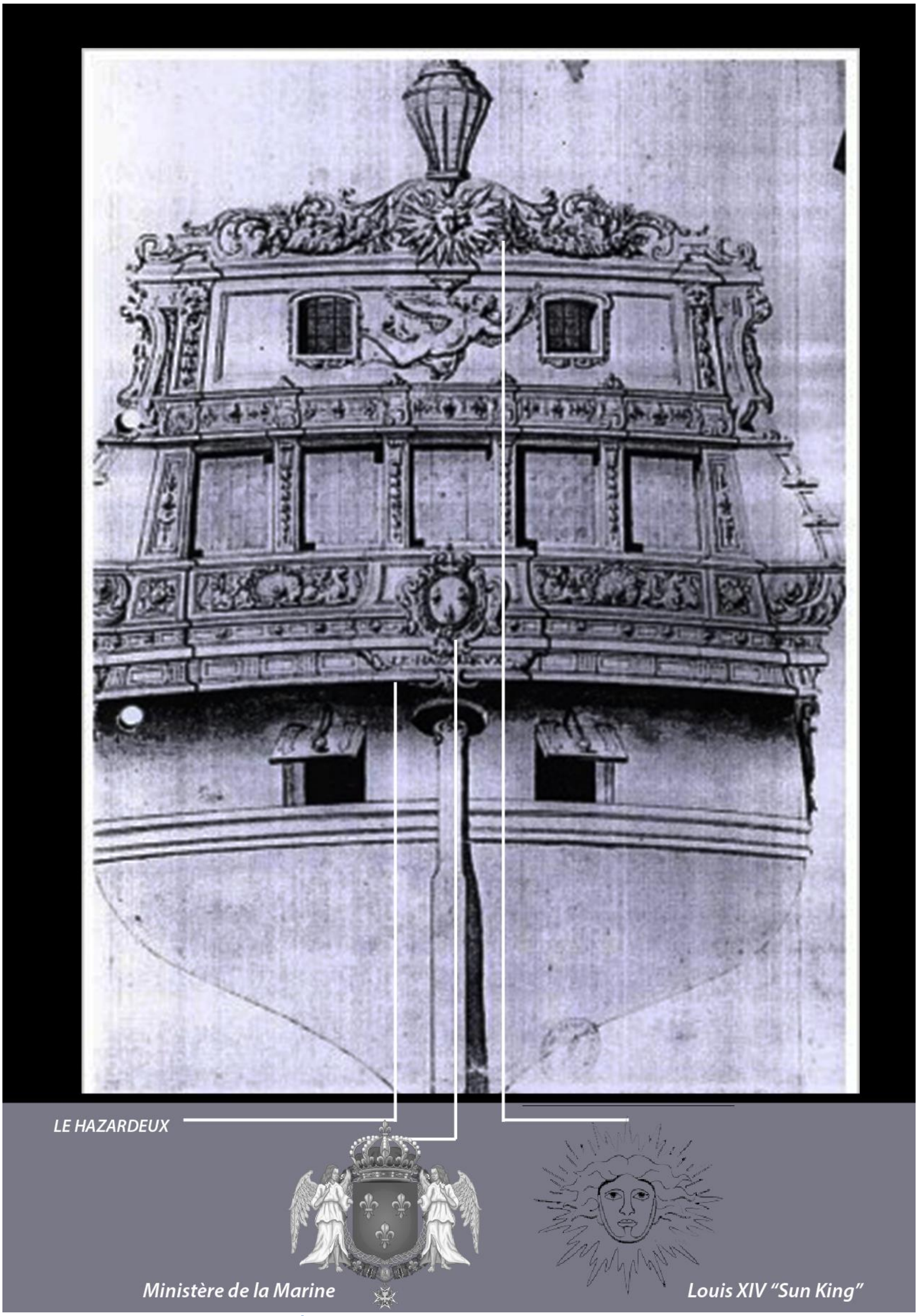

Figure 35. The stern of *Hazardous*, 17th Century. The image was taken from the Hazardous Project website and enhanced by the author (WHPPG 2018b)**. The original is held at Musée National de la Marine, Paris** (Uknown n.d.)**.**

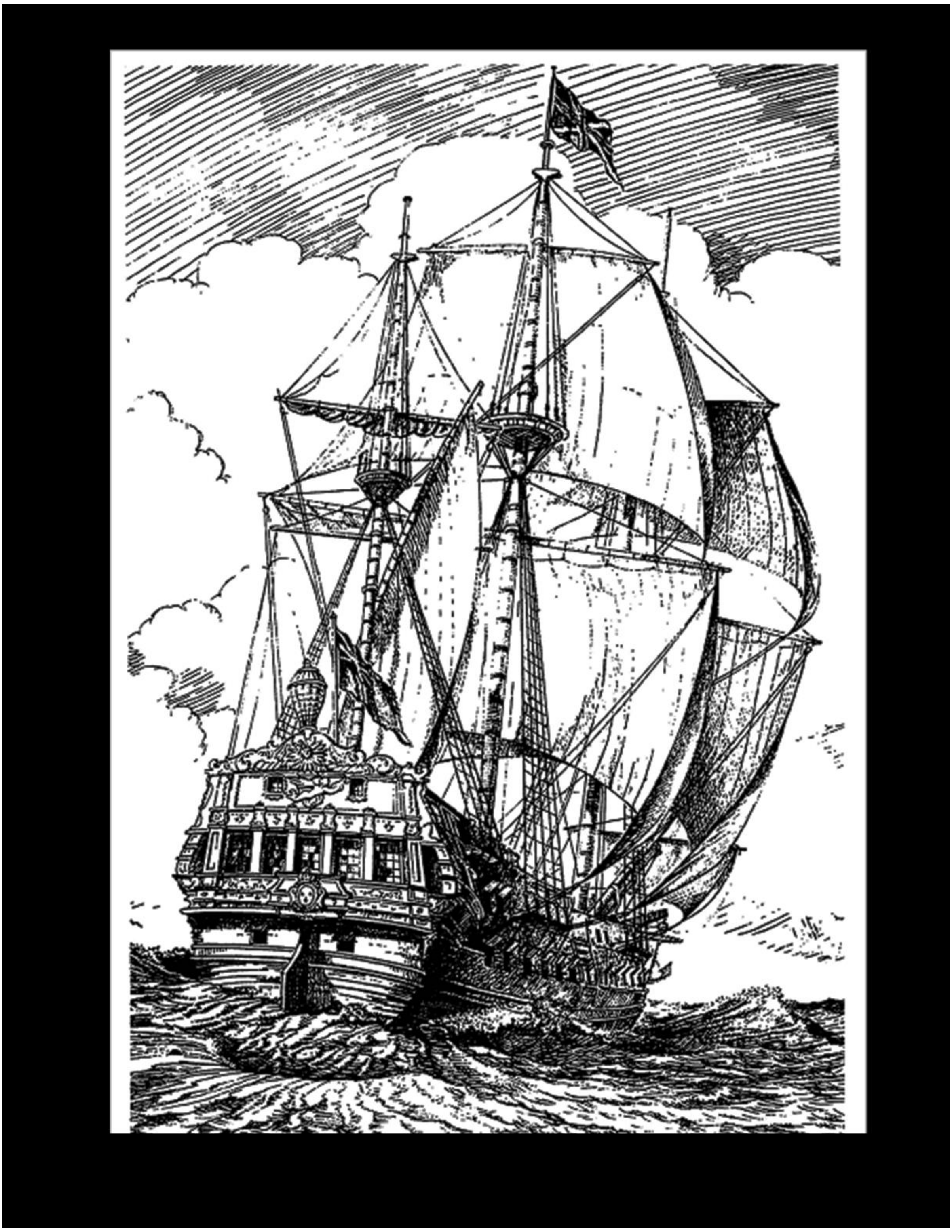

Figure 36. The *Hazardous* illustration, made by Lauri Crisp is based on a print of the stern found in the Museé Nationale de la Marine, Paris. The Image was taken and enhanced from the Hazardous Project website (WHPPG 2018c)**.**

Figure 37. The image shows shipbuilders, instructing at the yard, such as François Coulomb did with *Hazardous in 1699.* Port Mahon in the background (Ozanne 1752)**, Illustration for *Traité de construction des vaisseaux* (Treaty or the construction of ships) by Duhamel de Monceau** (Duhamel du Monceau 1752)**, made publically available by the University of Toronto. The original is held at Musée National de la Marine, Paris.**

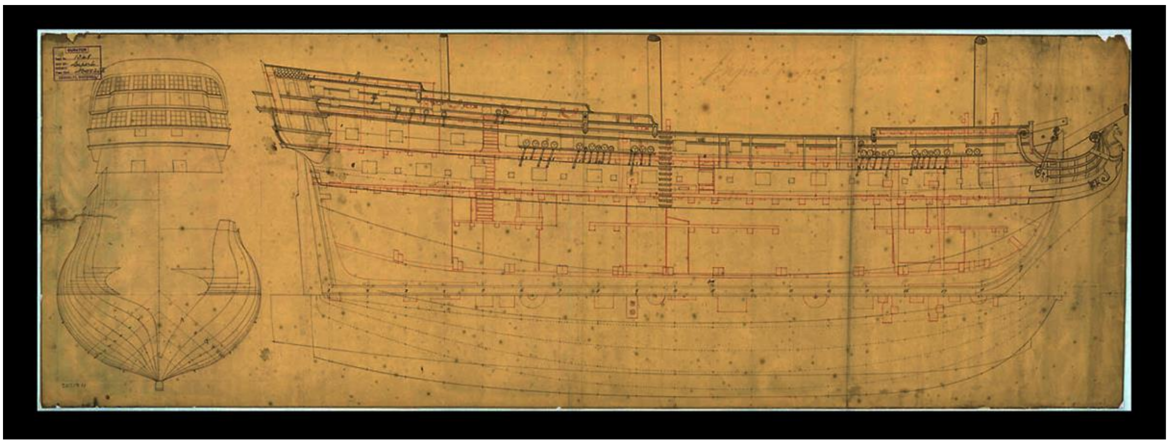

Figure 38. The image shows the lines plan of *Le Superb*, after her capture in 1710 (Uknown n.d.)**. The original plan is held at the National Maritime Museum. The author of this thesis enhanced the image to make the lines clearer.**

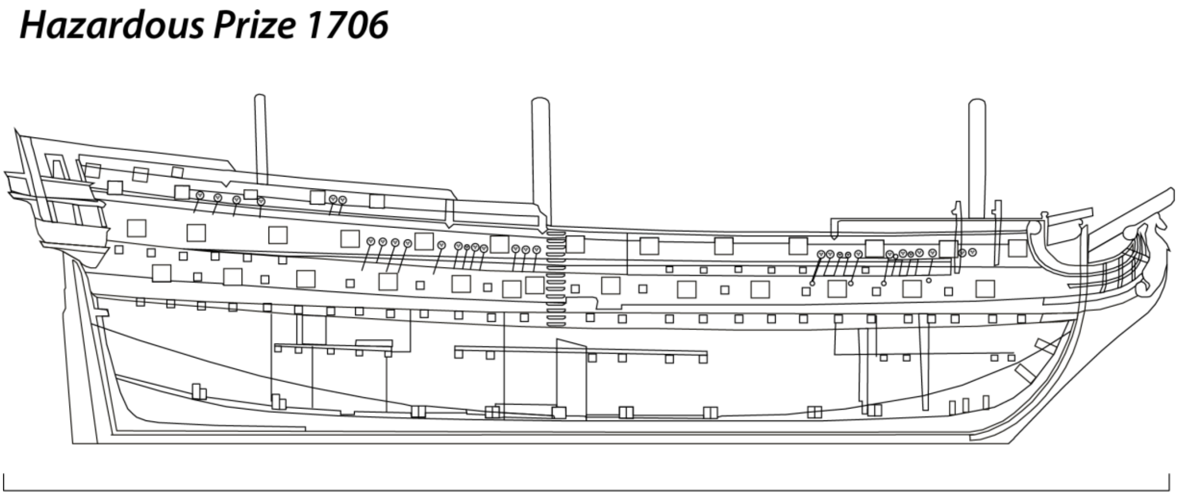

Figure 39. The figure shows the hypothetical lines plan of *Hazardous* 1703, based on the original lines of another French Fourth-rate, also captured by the British, *Le Superb* is shown in the previous figure.

The historical records on *Hazardous* are very limited in terms of the shipbuilding techniques used on the vessel. This is a common problem with late 17th century ships and, therefore the archaeological record offers greater depth and detail. One of the particularities of the *Hazardous* is the high number of lead strips found all over the site. It is believed that these lead strips are used as caulking because they have been found driven between the planking, and some of the pieces examined showed indentations caused possibly by a caulking tool[254] (Owen 1988, 1991). The caulking was held in place on the outer seams by parcelling consisting of a resin-soaked cloth under lead strips. The lead strips were held in place with tacks, the shafts of which were forced into the caulked seam, not into the planks themselves (Rosloff and Arnold 1984:293). This technique has also been observed on other earlier wreck sites, such as the *Seychelles* Portuguese wreck mid 1500's (Blake and Green 1986:5) the *Pepper Wreck* [255] (Castro 2003:14–16), the *Emanuel Point II* (1559) (Wallace 2012:37–38), the *Angra B* or the "Lead-sheathed Wreck"[256] (Crisman 1999:260) and the 16th Century *Molasses Reef* wreck (Oertling 1989:241). The general consensus is that this technique is believed to protect from *teredo navalis* (shipworm)[257] damage, and while the worms would have had no problem reaching the seams from within the planks themselves, the strips of lead prevented direct access (Björdal et al. 2012; Crisman 1999; Owen 1991; Weigelt et al. 2017).

The use of lead caulking was abandoned shortly after *Hazardous* wrecked, as these lead strips are not commonly found on other wreck sites of the 18th century. Another particularity of the *Hazardous* is the lead plates found between the inner and outer planking on the bow breast hook and other sections around the wreck (Figure 40 and Figure 41).

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[254] Traditional caulking on wooden vessels drives cotton or hemp fibers between the planks to make a water tight seal. These fibers are driven with a caulking mallet and a tool called a caulking iron, which is similar to a chisel. On *Hazardous* lead caulking was used extensively along the ship instead of fibers, and that is a rare feature.
[255] Tentatively identified as the Portuguese Indiaman Nossa Senhora dos Murtires 1606 (Castro 2003 and Castro *et al* 2010)
[256] Lead-sheathed Wreck at Porco Novo, Azors, is very likely Iberian in origin, and probably dates to the 16th or 17th centuries (Crisman 1999: 261).
[257] *Teredo navalis* are molluscs typically associated with natural and man-made wood such as mangrove roots in tropical regions, coastal protection and harbour facilities as well as floating structures such as wooden ships and driftwood.

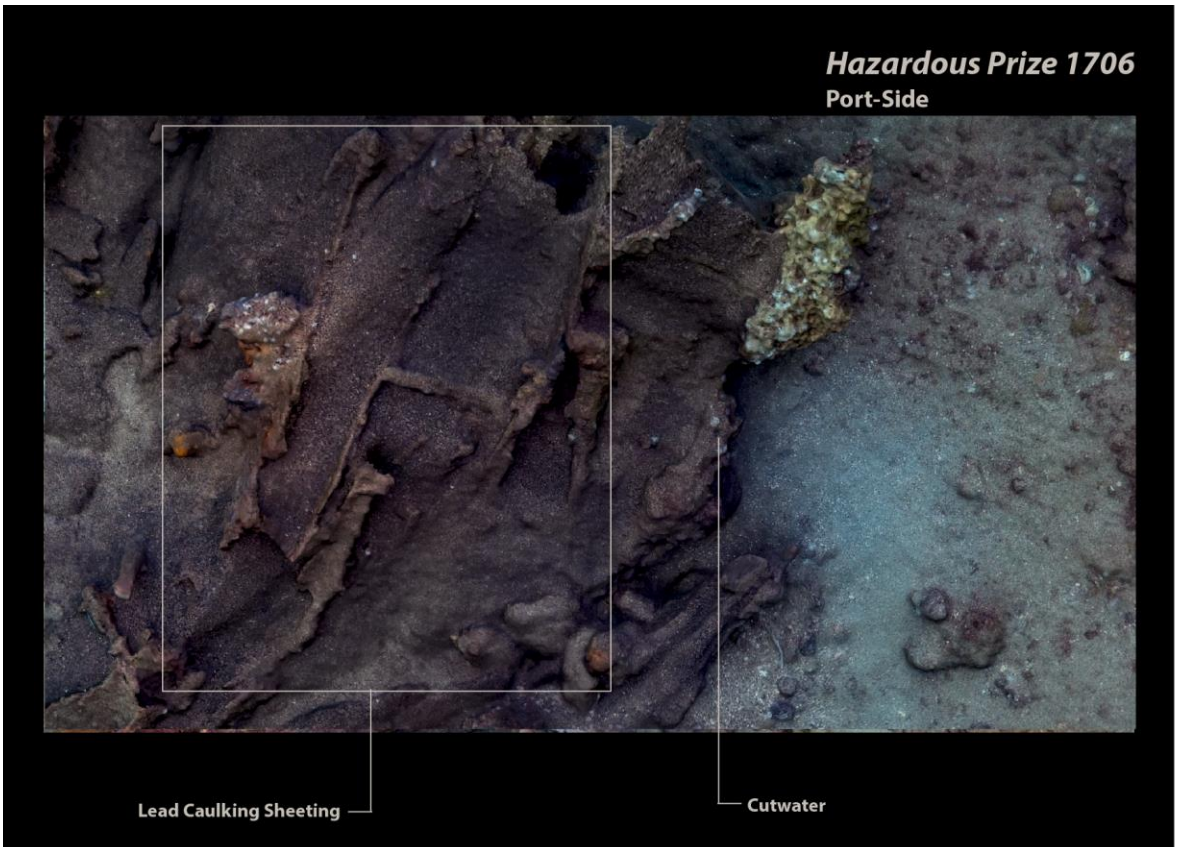

Figure 40. The image shows lead caulking sheeting at the bow section of the wreck. The image was generated with photogrammetry in Photoscan Agisoft Pro® and rendered in 3DsMax®. The pictures were previously colour corrected with Adobe Lightroom® the image was edited in Adobe Photoshop® and Adobe Illustrator ® by the author of this thesis.

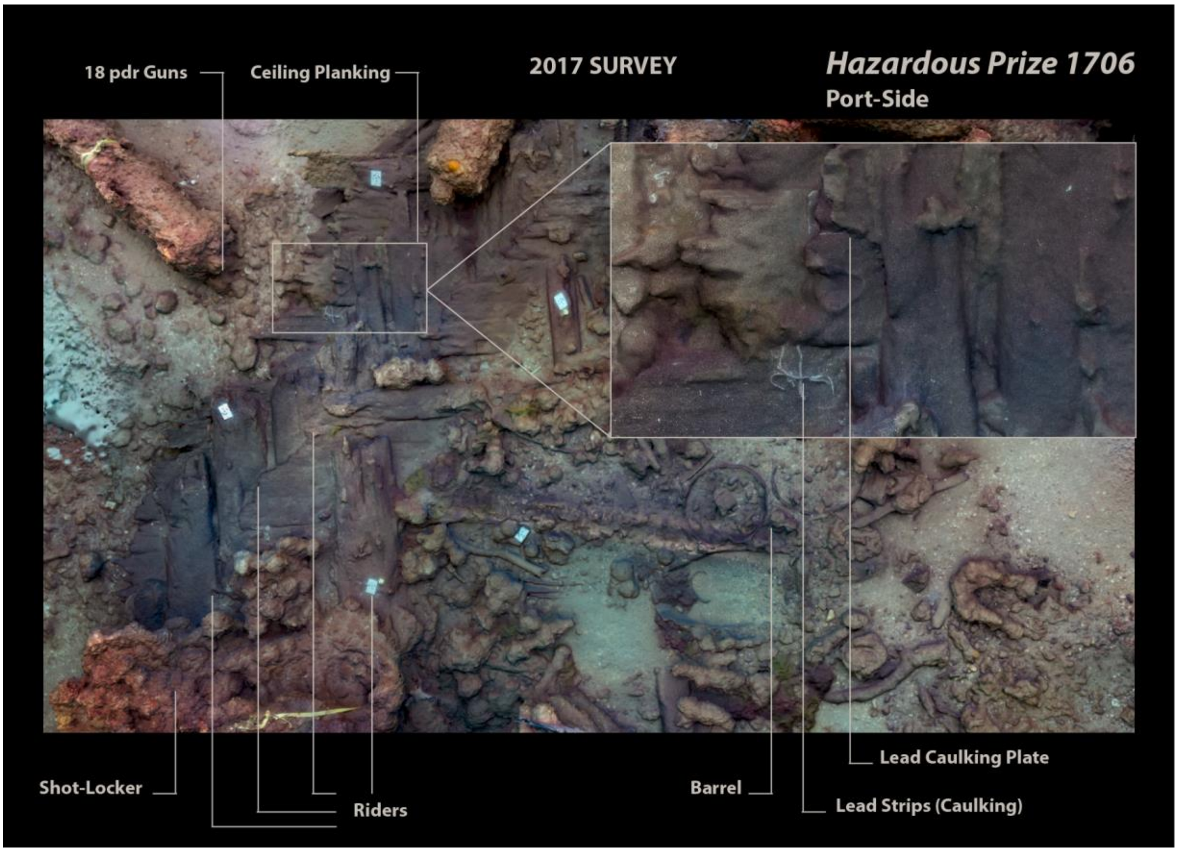

Figure 41. The image was generated with photogrammetry in Photoscan Agisoft Pro® and rendered in 3DsMax®. The pictures were previously colour corrected with Adobe Lightroom® and the image was edited in Adobe Photoshop® and Adobe Illustrator ® by the author of this thesis.

5.1.1 The Wrecking

On 17th September 1706, *Hazardous* set sail from Chesapeake Bay, Virginia as part of a convoy of 180 ships heading towards the Thames Estuary. She was escorting a merchant fleet along with three other men-of-war, the *Greenwich*, the *Woolwich*, and the *Advice* (Owen 1988:286). This was the largest Virginia convoy fleet to the leave Chesapeake in decades. The convoy ran annually until the break of the American Revolution in 1776 (Bradburn 2011; Magra 2016:27–28; Middleton 1946; Tucker 2017). The merchant fleet represented an import income for the Crown, carrying goods from the colonial trade such as sugar and tobacco, hence the pressure to leave and carry out the Atlantic crossing even in bad weather conditions. In 1706, the late start and winter passage meant great losses for the convoy as many ships were sunk, foundered, or captured. It was estimated that the financial loss to Public Revenue was more than £150,000 (WHPPG 2018b).

On the 12th November, Captain Lowen from the *Advice* found the *Hazardous,* off Start Point, Devon with another 35 Virginia merchant ships bound for London. That same day Captain Richard Browne had tragically passed away, leaving in command Lieutenant John Hares. Captain Browne was buried at sea on the next day, with 20-fired guns from the *Advice*. It was Captain Lowen's suggestion to continue the voyage, towards the Downs, off Kent, instead of seeking shelter in Plymouth. On 18th November the weather had worsened, so the convoy made St Helens, off the Isle of Wight. The *Hazardous* failed to anchor overnight at St Helen's. She was blown across the bay by strong winds. It was inevitable, and the *Hazardous* wrecked off Brackelsham Bay on the West Sussex coast on 19th November 1706 (Cobbett 1810:643; Owen 1988:286; Pascoe Archaeology 2018a; WHPPG 2018b)[258]. The 320 men board manage to make it to the shore, as this was only 800 metres away.

It is likely that *Hazardous* broke her back amidships on the edge of the reef, whilst her bow deeply buried in the soft silt stayed in position. The detached stern section slewed

[258] Unfortunately neither Captain's nor Lieutenant's Logs from *Hazardous* after February 1706 survived the wreck. Details concerning the Virginia convoy where extracted from the *Hazardous* Master's Log and the Captain's Log from *Advice* (WHPPG 2018a).

around, with the tide and wind movements, depositing artefacts from the officer's quarters in the stern in an area extending from amidships to the stern area (Owen 1991:332) (Figure 41).

On 27th December 1706, a Court Martial followed for Captain Lowen in which he was found guilty of causing the wreck of the *Hazardous* through his negligent behaviour and was dismissed from service (Owen 1988:286; PRO ADM I/5266 1706). He had an '*Ill Conduct*' for not going into Plymouth when he could have given '*ye ship in so ill a condition as to ye Sickness of his men and his want of Provisions', and later* for *steering an improper course and thereby bringing both her and ye Hazardous into Shoale Water* (PRO ADM I/5266 1706; WHPPG 2018b).

5.1.2 The Salvage

The Admiralty pay books show a party of ten, headed by Lieutenant Hares, was listed on *Hazardous* from 20th November 1706 until February 1707. It appears that this party was formed to undertake salvage on the *Hazardous* wreck site. The record shows that the wreck of the *Hazardous* sold at Portsmouth 1707 Sept. 30 (Uknown 1709). It is uncertain how much was salvaged then. A later attempt at salvage of the site took place in 1715 when documents in the Dockyard Archives at Portsmouth indicate that six brass guns and six iron guns were removed in two separate salvage operations (Owen 1988, 1991:330). One of the guns sent to the Board of Ordnance at Woolwich. The Calendar of Treasury Books shows a payment in the financial year 1715/1716 of an unspecified amount to "*Capt John Meric Cole, for salvage from the Hazardous man of war near Chichester*"(PRO WO 47-29 1715):

'*search and weigh six culverin iron ordnance said to be taken from the wreck of the Hazardous man of war, as by his request delivered into the Board by Capt. Cole and report whether they are serviceable or unserviceable*' (PRO WO 47-28 1715).

It seems that after 1715, no further salvage attempts were made on *Hazardous.* As the archaeological record testifies, the stores on the lower part of the ship were inaccessible, leaving many artefacts, including several guns (See Figure 52 to Figure 57).

5.2 Previous Work on Site

In 1977, two divers from Chichester Sub-Aqua Club, George Arnold and Buster Geary found the wreck site by accident while hunting flatfish in the bay (Owen 1988:285). For over 30 years, the Warship Hazardous Prize Project Group[259] (WHPPG 2018c) have carried out continued efforts to monitor and record the site. The vocational group, composed of professionals of different disciplines and backgrounds, includes archaeologists, conservators, surveyors and trained NAS[260] members (NAS 2018). This has allowed the WHPPG to carry out pre-disturbance and post-disturbance surveys as well as localised excavations targeted to a better understanding of the site. As a result of the WHPPG, the site has been listed as a protected wreck site under the Protection of Wrecks Act (1973) since 1986. With the support of publicly funded bodies such as EH[261] (2015) and later HE[262], further archaeological and geophysical assessments have been carried out by ADU[263] (ADU 2001), WA[264] (2004, 2015) and HWTMA[265] (2006). The WHPPG has benefited from the support of individuals and organisations from both the educational and commercial sectors throughout the years, with software, research and divers. The project has consistently produced annual reports: 1994-2016 (Grant 2017 and 2018 *forthcoming*) (Grant 1995, 1996, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 1997, 2015, 2016, 1998, 1999, 2000, 2001, 2002, 2003, 2004; Owen 1994), articles (Owen 1987, 1988, 1991; Owen, McKee, and Perkins 1986) and a website (WHPPG 2018c) (Table 23). From 1998 to 2011, the HWTMA was the archaeological advisor for the Hazardous Project Group,

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259 Previously known as Hazardous Project Group.
260 Nautical Archaeology Society (NAS) is dedicated to advancing education on nautical archaeology to everyone –its members, the general-public and across the global archaeological sector.
261 English Heritage was in charge for the protection of Wrecks until April 2015. English Heritage separated into two different bodies: new charity retaining the name English Heritage and Historic England.
262 Historic England (HE) is the Government's statutory adviser on the historic environment and, as the National Curator for England. HE is currently in charge of protecting, monitoring and safeguarding Coastal, Marine and Maritime Heritage.
263 The Archaeological Diving Unit (ADU) based at the University of St Andrews, Scotland. They surveyed, excavated and monitored wrecks from 1986 to 2002.
264 Wessex Archaeology (WA) Coastal & Marine division are an archaeological diving contractor.
265 Hampshire & Wight Trust for Maritime Archaeology, existed from 1991-2013, they are currently registered as the Maritime Archaeology Trust (MAT).

however, the team was primarily made up of members of the 308 Sub Aqua Club.

In 2013, partly funded by Historic England, the HWTMA encouraged the Hazardous Project Group to create a diving trail on site. It was set up to explore the wreck and the surrounding environment (WHPPG 2018a). However, the dynamic environment demanded a great deal of maintenance of the station-buoys and cables thus requiring a vast amount of resources. Currently, the diver trail is in a very poor condition and at present is unserviceable (Grant 2016:7).

The WHPPG has been open to research projects interested in the better understanding of the wreck site. From 1994 to 1996 an environmental study of the impact of sewerage was done by Merret-Jones (2000), from the University of Surrey. Merret-Jones used data loggers to understand site conditions (Water quality analysis[266], water sample analyses, and timber analyses). Also, trace the study of artefact mobility on the site by Holland (2002), University of Southampton. The study was further extended from 2004-2006, in the attempt to trace artefact movement on *Hazardous* (Holland 2015:125–89, 329–30).

A condensed chronology of events since the site's re-discovery in 1977 to 2018 summarises research activities carried out by a number of people and institutions to understand the site formation process of *Hazardous Prize* (Table 19).

Year	Chronology of research carried out on *Hazardous Prize*
1977	• Re-discovery of the wreck by George Arnold and Buster Geary.
1979-1984	• The site was visited regularly by members of the recently formed 308 Club Branch of the Sub-Aqua Association (Owen 1988:287)
1986	• Licensee Mike Perkins[267] followed by Licensee Norman Owen (1987-1995) • A substantial drop in seabed levels was noted in 1984, revealing timber and artefacts. The seabed consists of fine sand to the north of the wreck and rock formations to the south, east and west. The site is exposed from all wind quarters, except the north and east. • Tidal currents reach a max of the ½ knot on the ebb at spring (Owen et al. 1986)

[266] Temperature, pH, dissolved oxygen, turbidity, salinity, and depth.
[267] Named as the licensee because of his museum and conservation facilities

Year	Chronology of research carried out on *Hazardous Prize*
1987	• Two guns were raised for conservation (Fig. 58). • A substantial drop in seabed levels noted from the winter of 1986-1987. This drop has uncovered for the first time, a substantial amount of timber frame ends on the east and west side and planking, mainly in the north end of the site (Owen 1987)
1988	• *IJNA*[268] article of Pre-disturbance surveys, with an initial site formation analysis (Owen 1988) • Winter of 1988/1989 saw a continued drop in seabed levels, exposing more of the site
1989	• The southern section of the wreck was recorded. • The ADU, 208 SAA Club and the Mary Rose BSAC group formed the support team. • A substantial drop in seabed levels. Artefacts in danger of loss due to drop in seabed levels • Attempts to locate the keel or keelson failed but a large timber that may be the foremast step was identified[269].
1990	• Archaeological advisor, Alexzandra Hildred of the Mary Rose Trust assess the iron gun on a trucked carriage (Hildred 1990).
1991	• Second *IJNA* article with an interim report with the identification of the site as the *Hazardous* (Owen 1991). The article includes a full site plan including a section to the south. • In 1991, there was still debate if it could be the *Duc de Duras* (*Bonhomme Richard*[270]) or the *Eagle* 1703[271].
1992-1993	• Bad weather and poor site conditions limited the raising a gun carriage. It was decided to preserve *in situ.* • In the amidships area, seabed levels have dropped to clay bedrock. It appears that a section of collapsed decking has survived on top of hull timbers. • A data logger was placed on the seabed and wood samples (Merret-Jones 2000)
1994	• *The south-east corner of the site shows the area where seabed levels have dropped down to clay* (Owen 1994:1).
1995-6	• Sadly, licensee Norman Owen past away leaving the site in the hands of current license Iain Grant.

[268] IJNA stands for International journal for Nautical Archaeology
[269] This is highly relevant in terms of the understanding of the wreck and the site formation processes. The keel was located in 2017, due to natural erosion and sediment migration.
[270] Coverted from a 900-ton East Indiaman to 63-gun 3rd-rate (Boudriot 1987:8)
[271] Sunk during the Great storm of 1703. This wreck has been identified as the Protect Wreck Site of Tearing Ledges, off the Isles of Scilly, in Cornwall (Camidge and Johns 2017).

Year	Chronology of research carried out on *Hazardous Prize*
	• *Scouring in southern and eastern parts of the site caused new timbers to be exposed and exposed timbers to be moved off the site and loss* • ADU video survey (Grant 1996) • Site condition survey with data-loggers (Merret-Jones 2000)
1997	• It was thought that a large build-up of sand was noted at the south end of the site, this has remained and no ships timbers were visible in this area (Grant 1997). However, it was the opposite. That section had completely disappeared entire southern end lost forever (not buried, it was destroyed) (Johnston 2014).
1998	• A permanent display of artefacts from the site can be found at Earnley Gardens near Chichester.
1999	• The sand levels at the north end of the site appeared to be stable from the previous season
2000	• *Very little change to seabed levels was noted in either the north or south end of the site* (Grant 2000) • Participation of the HWTMA (Satchell 2000) and the NAS.
2001	• ADU dives on site • The diver trail was completed and booklets by the HWTMA were developed that explained each station along the trail (Grant 2001:1). • Due to very poor visibility and much bad weather, it was only possible to carry out limited monitoring of the site.
2002	• ADU Multi-Bean Eco-Sound (MBES) survey • Diver trail repairs were necessary because of damage over Winter 2001/2002 • Considerable seabed movement on the western side of the site adjacent to the hull timbers (Grant 2002)
2003	• WA carried out a MBES (WA 2004, 2015)
2004	• Tracer artefacts were placed on site (Holland 2015)
2005	• Poor weather conditions over the winter caused major shingle movement along the coast from the east. This resulting in making the slipway (less than 1000 metres from the site) unusable making winter diving impracticable (Grant 2005).
2006	• Some of the artefacts remain visible on the seabed, though far removed from their original locations. Many are 'missing', presumed buried or lost off-site. Conditions have not permitted a comprehensive survey to be undertaken this year (Grant 2006; Appendix B in Holland 2015:23). • HWTMA made a detailed report on environmental work up to 2006 including, data from monitoring points across the site and other environmental data (Grant 2006; Holland 2002; HWTMA 2006).
2007	With reference to the tracer artefact study: • Artefacts that were placed on-site in 2004 and periodically monitored, in order to observe artefact movement patterns and assist research into the site dynamics and

Year	Chronology of research carried out on *Hazardous Prize*
	site formation processes of the Hazardous site, have been largely dispersed and only a few remain within the main site area (Appendix B in Holland 2015:24). • A great deal of scouring has taken place from the north-west side of the hull structure around the beak and down the east side to just short of the cannonball mound. In some areas outside the hull structure, there has been a loss of up to half a metre of sand overburden, with the considerable undermining of the hull, in places down to fossil bed material (Grant 2007:4).
2008	• East and north of the hull, appears to have lost as much as 500mm of sand and general sediment. • The area appears to have large sections of hull planking with frames attached freshly uncovered, just east of the protruding hull frames. The area has never been exposed to this depth before (Grant 2008:1). • Finds from the wreck in the gulley 60m off the main site (Grant 2008:5).
2009	• The sand encroaching from the south appears to be increasing; the three guns to the south are completely covered (Grant 2009:5).
2010	• The seabed movement noted over the last two years, south, east and west of the main wreck site, has now increased throughout the whole of the main site, almost completely covering the diver trail (Grant 2010:4).
2011	• Sand movement and overburden in the area of the main site made it impossible to carry out any "diver trail" visits as most of the site is now buried to similar levels first observed by the author in the early 1980s. (Grant 2011:1).
2012	• Like last year, due to the continued sediment movement over the winter & continued through the summer months, the entire site is now covered with sand to a depth of over one metre in places (Grant 2012:7).
2013	• 2013-currently archaeological advisor Daniel Pascoe (Pascoe Archaeology 2018a). • There has been a drop in overburden levels around the east side of the cannonball mound (Shot-locker). • The timber of the beak shows considerable degradation from the activity of gribble worm on the exposed high points, the lead sheeting sandwiched between the timber layup of this area appears to be more exposed also • Reductions in the sand overburden of between 120mm & 410mm (Grant 2013:5)
2014	• WA MBES Survey on 2nd July The diving team located a possible mast cap (Grant 2014:5–6). • In the general area, there has been a reduction of up to half a metre in places, uncovering timbers in a pristine condition not seen by the author in thirty years diving on the site (Grant 2014:6).
2015	• As previously stated, weather conditions were very poor over winter

Year	Chronology of research carried out on *Hazardous Prize*
	• The cannonball mound & the three large cannons stand well proud of the seabed as last year • The cannonball mound & the three large cannons stand well proud of the seabed as last year (Grant 2015:3) • Publication of artefact trace study (Holland 2015)
2016	• The visibility was very poor on every dive. • Erosion in several areas within the main site, most notably within the hull on the west side amounting in places to an estimated 300mm. Similarly, the beak area is showing pristine timber uncovered within the hull amounting to approximately 400mm in places. There is a reduction in sand overburden both inside and outside of the frames on the east side of the hull remains (Grant 2016).
2017	• Addition of a new a Ground Control Point (GCP) network, measured in with DSM method. • The first extensive photogrammetry survey and excavation by the author of this thesis as part of the Hazardous Project Team (WHPPG). • The visibility was exceptionally good for a couple of dives that permitted to take the pictures for the survey.
2018	• The visibility this year limited the coverage for the photogrammetry survey. However, three more guns were added to the south and some areas were recorded during the excavation. • Survey and excavation by the author of this thesis as part of the Hazardous Project Team (WHPPG).

Table 23. The table summarises activity on *Hazardous Prize*, including archaeological research and environmental conditions.

5.3. Location and Hydrodynamics

The *Hazardous Prize* 1706 is located in the Eastern Solent, on the southern coast of England, West Sussex, approximately 800m off Bracklesham Bay (Figure 42). The wreck position was converted from OSGB36 to UTM30N from the designated protected wreck area that covers a radius of 100m from [272] (HE 2018b):

[272] The area has been designated since 1986 under the Protection of Wrecks Act 1973. The statutory Instrument is Order No. 1980/1307.

(OSBG36) Easting	(OSBG36) Northing	(UTM 30N) Easting	(UTM 30N) Northing
480670.291	95296.108	651057	5624461

(WGS84) Latitude	(WGS84) Longitude
50.75167	-0.85783

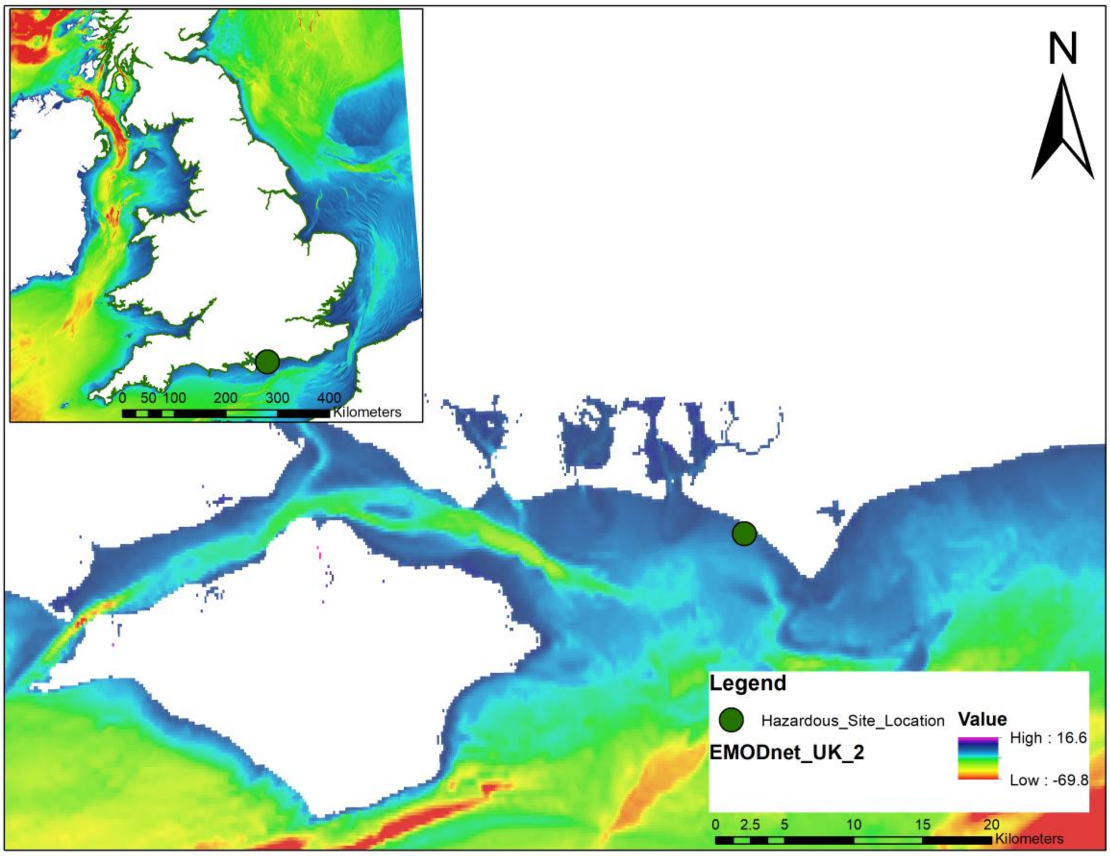

Figure 42. The map presented the Southern Coast of England, with the *Hazardous Prize* site location according to HE (2018b)**. The projected coastline is the World Vector Shoreline (WVS) from NGA** (National Geospatial-Intelligence Agency 2018)**. The bathymetry and UK territorial waters are sourced from EMODnet** (EMODnet 2018)**. Maps created by the author on ArcMap® 10.5.**

5.3.1 Site Conditions

The *Hazardous* is located in a high-energy environment (H2aS, see section 4.3 see Table 20), with elements of coherent structure and some artefacts. The remains of *Hazardous Prize* lie in a gulley formed by sublittoral biogenic reefs[273] in Bracklesham Bay (BGS

[273] Biogenic reefs are those that are created by the animals themselves. In the UK these include coral reefs, made by cold-water corals such as *Lophelia pertusa* and *Madrepora oculata*. Biogenic reefs can also be made by reef-building worms such as

2018a, 2018b; Connor et al. 2004:22; Ellwood 2011). The presence of offshore and nearshore banks, bars, shoals and reefs adds unusual complications to the sediment budgets of each of the several distinct littoral transport sub-systems (West 2018). The reef is overlaid with a layer of sand and the seabed in the area is highly dynamic and mobile, with continuous movement and changes in the level of the sand (Johnston 2014:2) (Figure 43).

The *Hazardous* is approximately 800 m from the shoreline, in 7m depth of water below Chart Datum. The regional tidal pattern is what is commonly called double high water (A tidal phenomenon resulting from the shape of the coastline and the water depth in the Solent region). During spring tides, the tide rises following Low Water but the tidal stream slackens some 2 hours before HW leading to a stand for up to 2 hours prior to a rapid rise to HW. The ebb tide is therefore associated with strong ebb currents. This ebb tide dominance is reflected throughout the whole of the Solent. Chichester Harbour entrance, for example, experiences a new 7-hour flood and 5½ ebb (New Forest District Council 2018:23, 24; Pugh 1989). This means *Hazardous* is in an high-energy tidal environment with infralittoral fine sand/infralittoral muddy sand according to the EuNIS classification (Connor et al. 2006; EMODnet 2018; Populus et al. 2017). Despite this, the site is in an area with a gentle tidal force compared to Chichester Harbour. Being such a shallow wreck, waves, and storms have a great impact on the seabed. The offshore wave climate is dominated by waves from the south and south-west with periodic episodes of less energetic waves from the southeast (SCOPAC 2018a; Wallace 1990).

On a macro-scale level, the site is being degraded through two principal mechanisms: long-term net sediment loss across the whole of Bracklesham Bay and isolated storm events (HWTMA 2006:53). On a meso and intra-site level, based on dive logs, and archaeological reports from the Hazardous Project, the HWTMA identified three main areas: high archaeological potential, the area of loss and areas of degradation (Figure 44). Holland (2015:188) also highlighted these potential areas and studied them with her tracer experiment. Holland (Holland 2015) traced the movement of tracer artefacts

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the honeycomb worm *Sabellaria alveolata*, the ross worm Sabellaria spinulosa and the serpulid worm Serpula vermicularis. Mussels such as the edible mussel *Mytilus edulis* and the horse mussel *Modiolus modiolus* can also create biogenic reef structures (JNCC 2018).

across the site, to understand the site dynamics of the seabed. Tracing the artefact distribution represented a challenge on such a dynamic site such as *Hazardous,* with limited visibility throughout the year that makes it complicated to map their movement. However, this has the potential for ongoing management strategies (Holland 2015:188).

The *Hazardous Prize* wreck site has had different approaches to understand sediment migration and seabed dynamics. Although, the resolution of the data has had a direct impact on the understanding of site dynamics. *In situ* observation for over 30 years found in the WHPPG dive logs represent the longest direct record of sediment changes on the wreck site in the UK, with eyewitness accounts. Although this is extremely valuable information it is also insufficient to interpret sediment regimes, as previously attempted (Holland 2015; HWTMA 2006). The methodology proposed by the HWTMA consisted of the direct measurement of metal rods, used as control points. The use of only 10 points results in an insufficient analytical approach to comprehend sediment analysis. However, it is understood that this was aiming for a low-cost technique for projects with a limited budget. The main issues to take into consideration with direct measurement of sediment control points are as follows:

- The complete reliance on having the monitoring points remain in place.
- The limitation of having 10 points only offer a limited coverage of m^2 area.
- The size of the poles limits the range of sediment that is measured.
- The effect of scouring and/or accretion due to the placements or measuring poles
- The possibility of a build-up compound error from a diver taking a measurement with a tape, writing it down underwater, then recorded and later analysed. In addition to the aggregate error of using measuring tapes with an upstanding structure that bend and turn the tape.
- Most importantly, the limitation of having a measurement that depends on diving days, that rely on volunteer availability and weather conditions.

The site plan from 1991 (Owen 1991) was used by the HWTMA to reference the sediment level monitoring points that identified a general sediment budget pattern with areas of accretion and erosion. Furthermore, the compilation of data from the dive logs (1986-2006) as well as the recovered artefacts revealed areas of archaeological potential on the site (HWTMA 2006:52) (Figure 44).

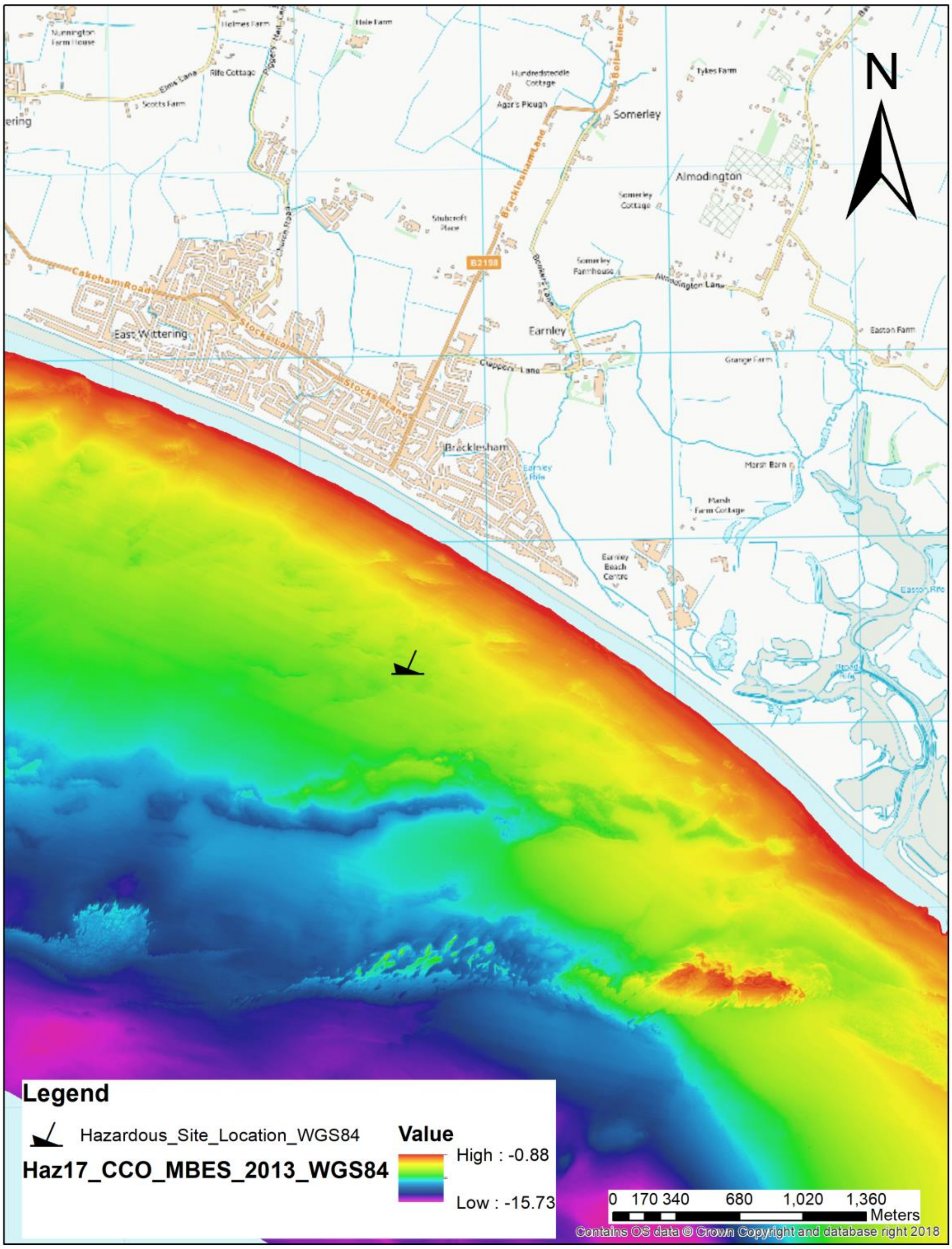

Figure 43. ***Hazardous Prize*** **location showing the surrounding reefs on the MBES survey of Bracklesham Bay, done by the CCO** (CCO 2018)**. The wreck location was converted from OSGB36 to WGS84 30N, with the original position from HE** (2018b) **The coastline shows ©Open Street Map 2010 based on ©Ordnance Survey 2010. The author of this thesis with Arc Map 10.5® created the map.**

Figure 44. The site plan is based on Owen (1991:333) **and the areas (High archaeological potential, the area of loss, Area of degradation) on HWTMA** (2006:57)**. Created by the author of this thesis with Arc Map 10.5®.**

5.4. Seabed Geology and Sediment Transport

The seabed geology or seabed stratum is a critical factor for site preservation[274] for physical, chemical and biological erosion of the wreck. The mobility of the seabed will have a direct impact on the state of preservation of the wreck (structure coherence and distribution of structural elements and artefacts). Therefore, it is important to have an understanding of a macro, meso and intrasite level of the seabed composition and its dynamic movements.

5.4.1 Geology

The SCOPAC[275] sediment transport pattern study shows the long-term sediment movements along the coastline, demonstrating the contrary and complex sediment transport pattern within which the *Hazardous* lies. The Bracklesham Group comprises interbedded to interlaminated clays, silts and mostly fine- or medium-grained sands, locally shelly. Glauconitic[276] silty fine-grained sand occurs in the mid part of the sequence. Minor coarse-grained sands, fine gravelly sand, gravel beds, sandstones or ironstone concretions occur in places (BGS 2018b, 2018a).

5.4.2 Sediment Transport

The seabed is a highly dynamic environment subject to significant, unpredictable and rapid natural change and movement evidenced by cycles of sediment accumulation and scouring (Johnston 2014:3). These cycles are required to be monitored with a high-resolution MBES time-series to be better understood, such as presented in Chapter VI on the *Rooswijk.* However, with the available data, it was only possible to delimit areas of erosion and sediment loss over a quasi-decal (11-year) cycle. The Bracklesham Beds occur along the sea coast of the Selsey Peninsula, from Chichester Harbour to Pagham Harbour, though they are locally much obscured by recent beach deposits (Curry et al. 1977) while exposure of the solid geology depends on the state of the tide and the shifting beach sands and shingle (JNCC 2007:1) (Figure 45 and Figure 46).

[274] Further dicussed in Chapter IV, section 4.1.4.
[275] Standing Conference on Problems Associated with Coastline (SCOPAC).
[276] Glauconite is almost exclusively found in peloidal forms, i.e., ovoid shapes, in sediments, sandstones, and carbonates (Velde 2003:311, 312).

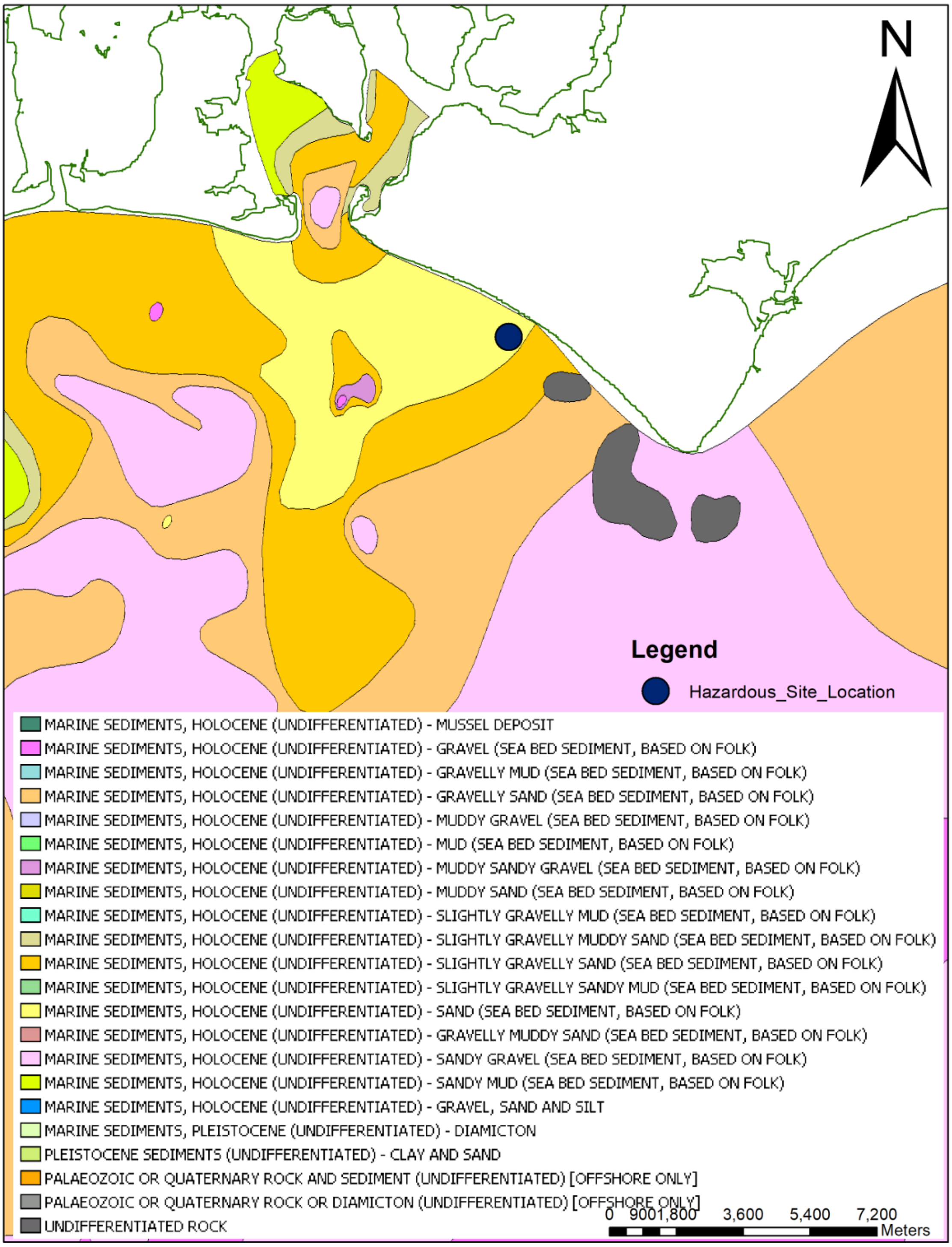

Figure 45. BGS offshore classification based on Folk (BGS 2018b; Long 2006). The author of this thesis mad the image in ArcMap 10.5®.

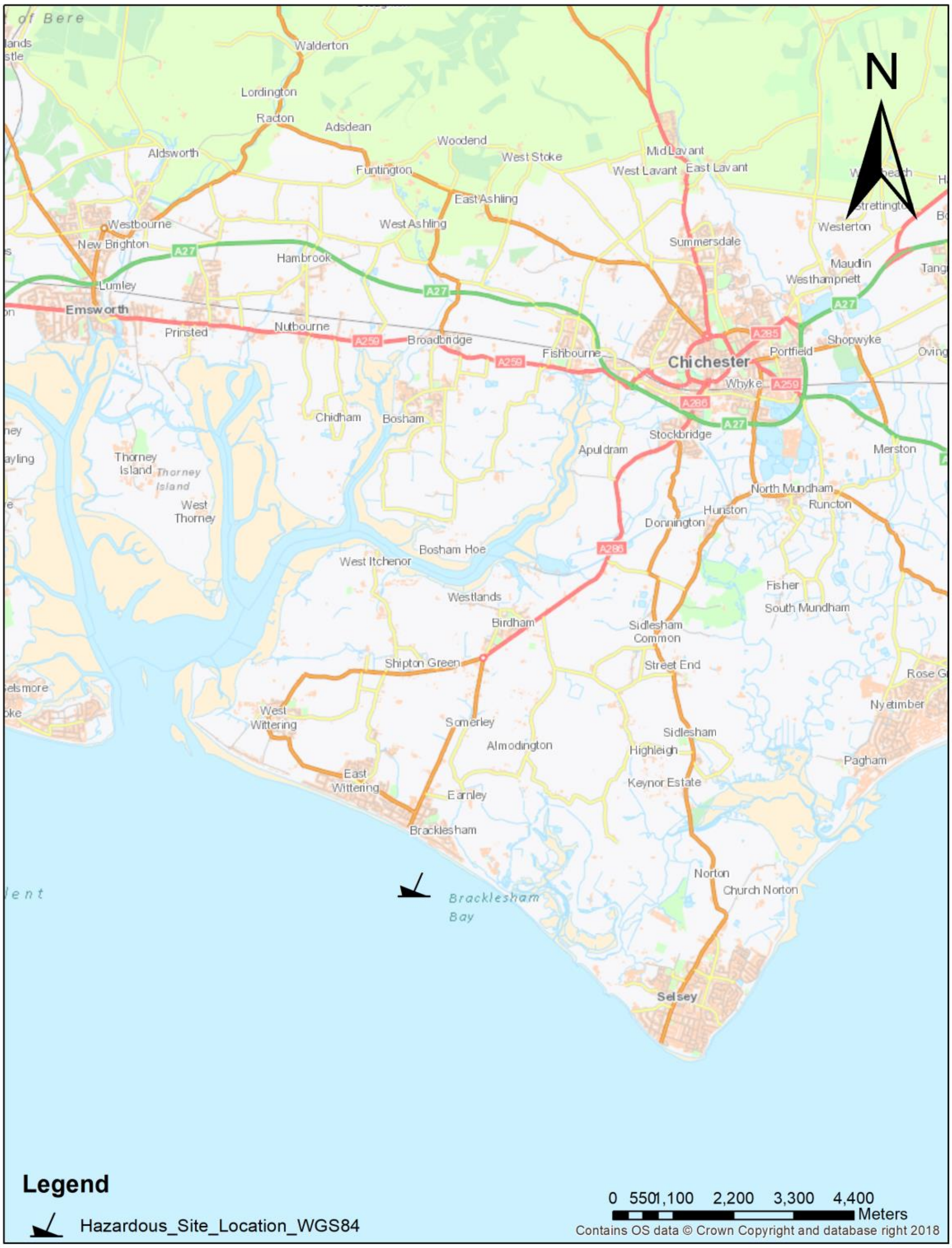

Figure 46. The coastline shows ©Open Street Map 2010 based on ©Ordnance Survey 2010 ©Crown Copyright and database right 2018. The author of this thesis created the map. with Arc Map 10.5®

5.4.3 Tides

The tidal flow in the Eastern Solent tends to be dramatically slower in comparison to that of the Western Solent (Tubbs 1999:15–17). The tidal range is 4.9 m (during springs[277]) and 2.7 m (during neaps (NOAA 2018e)) at Pagham Harbour mouth and at the entrance to Chichester Harbour, with the ebb phase shorter than the flood[278](NOAA 2018a). The early ebb stage gives rise to rectilinear, nearshore parallel, residual currents off the east-facing coastline. The stream moves towards the banks and reefs south of the Bill (Selsey). This rectilinear stream goes across the *Hazardous* in a north-westerly/south-easterly direction. However, during the peak ebb flow, the movement is north/north-eastwards. The maximum surface currents are between 1.4 ms^{-1} (springs) and 0.7 ms^{-1} (neaps) (Owen 1988, 1991), reducing slightly at the seabed.

Tidal currents are adjacent to the west/south-west facing coastline and flow predominantly eastwards/south-eastwards, as indicated by general seabed morphology with sand waves (HR Wallingford 1995, 1997; Wallingford 2000). The protrusion of the Selsey peninsula into this net eastwards moving tidal stream creates an anticlockwise circulating gyre, (or "back-eddy") to the north-east, where residual current speeds are between 0.3 to 0.4 ms^{-1} at the peak of the flood stage (SCOPAC 2018a; Wallace 1990).

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[277] Springs tides happen during full or new moons. This occurs when the Earth, sun, and moon are nearly in alignment making the average tidal ranges slightly larger. This event takes place twice each month. The gravitational pull of the sun is "added" to the gravitational pull of the moon on Earth, causing the oceans to bulge a bit more than usual. This means that high tides are a little higher and low tides are a little lower than average. The opposite is called neap tides, seven days after a spring tide, the sun and moon are at right angles to each other. When this happens, the bulge of the ocean caused by the sun partially cancels out the bulge of the ocean caused by the moon. This produces moderate tides known as neap tides, meaning that high tides are a little lower and low tides are a little higher than average. Neap tides occur during the first and third quarter moon, when the moon appears "half full." (NOAA 2018).

[278] Tidal currents occur in conjunction with the rise and fall of the tide. The vertical motion of the tides near the shore causes the water to move horizontally, creating currents. When a tidal current moves toward the land and away from the sea, it “floods.” When it moves toward the sea away from the land, it “ebbs.”

5.4.4 Wave and Storminess

The offshore wave climate is dominated by waves from the south and south-west with periodic episodes of less energetic waves from the south-east (SCOPAC 2018a; Wallace 1990). However, the shoreline wave climates are complex, as the east and west facing coastlines have contrasting orientations and western parts of Bracklesham Bay are partially sheltered by the Isle of Wight (DEFRA 2018; Halcrow 2002) [279].

5.4.5 Energy

The natural factors that have an impact on the wreck are better understood on a macro-scale, using the attribute of energy[280]. The energy level encompasses wave exposure, sea horizon, tidal currents, biozones, depth, distance to the coast and substratum.

In sum, the *Hazardous* lies in a high-energy environment, in shallow water, making it vulnerable to storm dominated erosion (wave and wind). *Hazardous* is mainly exposed to storm activity coming in from the south and a southwesterly direction (Figure 47). The long-term changes are subject to tidal dynamics that dictate the seabed movement (Figure 47). The *Hazardous* lies on a mobile sandy seabed that overlay on top of glauconitic sands and green clays bed.

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[279] The Department for Environment, Food and Rural Affairs (DEFRA) is the government department responsible for safeguarding the natural environment, supporting the food and farming industry, and sustaining the rural economy in the UK.

[280] Further explanation is found in Chapter IV, section 4.1.5.

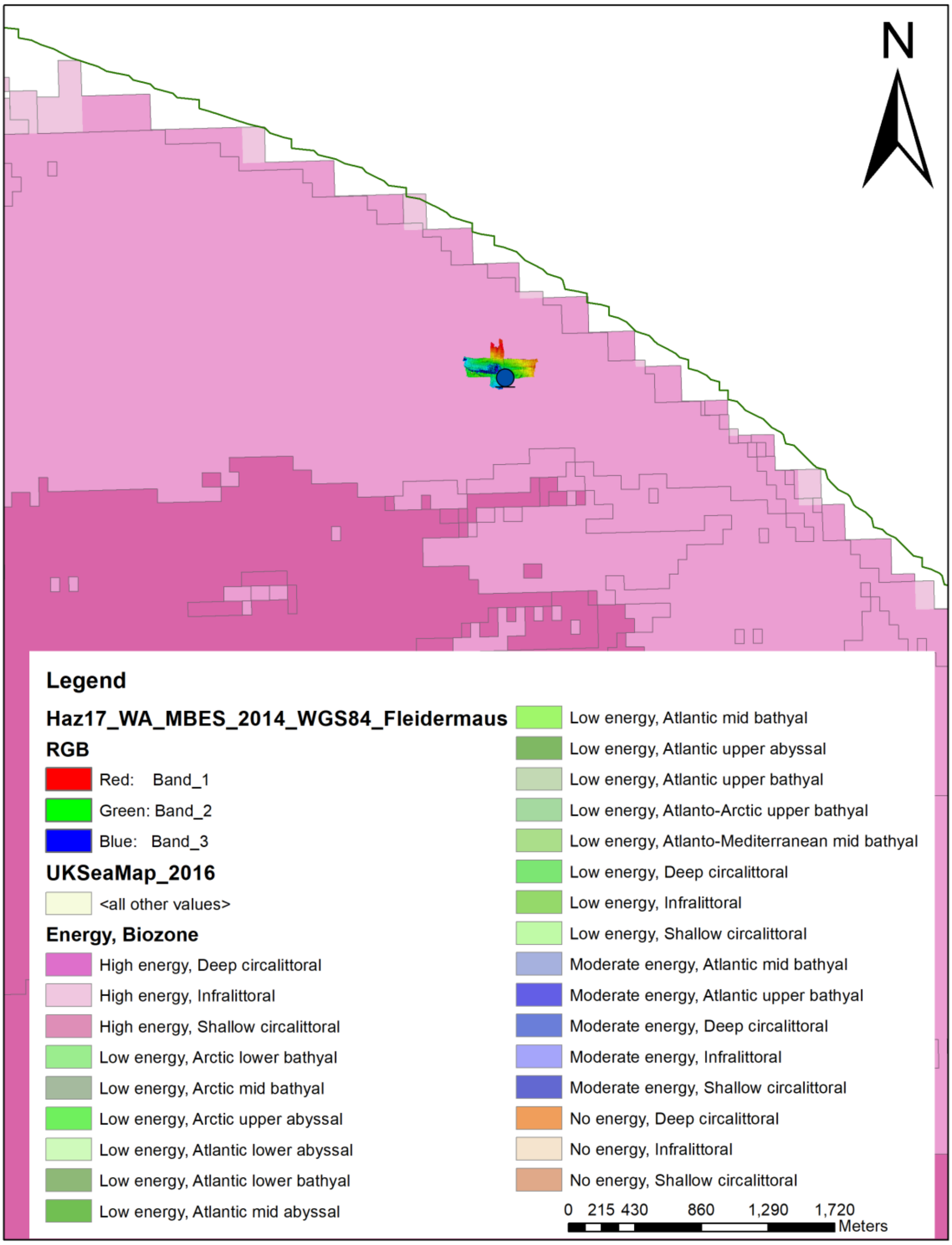

Figure 47. The map shows Energy and the Biozone according to EMODnet (EMODnet 2016, 2018; Populus et al. 2017)**. The *Hazardous Prize* is located in a High energy shallow circalittoral environment** (EMODnet 2018) **and MBES from WA 2014** (WA 2015) **kindly provided by HE.**

5.5 Materials and Methods

The main contribution of this methodological approach is the multiple scale analysis that is achieved by a true integration of 4D time-lapse generated by remote sensing techniques, historical sources, and *in situ* observations. Data availability will depend on site conditions, as well as budget, resources, and availability from the main WHPPG team.

The first stage of understanding the site formation process of *Hazardous* was to asses all the data that was collected on site previously (historical, remote sensing, site plans, dive logs, reports, and publications).

The assessment of the marine geophysics for the site included: Multi Beam Eco-Sounder (MBES), ADU (2002), WA (2003 and 2014), the side scan sonar (SSS), WA (2014), and magnetometer (MAG), WA (2014). The MBES data, in particular, brought to light two main problems: poor resolution (50 cm) and limited or no access to unprocessed data (RAW) files[281]. HE was kind enough to provide the closest thing to the RAW data, (.xyz, or .pts) that allowed the author to re-process and create the maps for this thesis. This could be easily solved in future surveys by requesting the surveying contractor to comply with key points highlighted by HE in 2013 (Plets, Dix, and Bates 2013:11), as follows:

- Project background, methods and results.
- Description of the survey's coordinate system (including Datum used for depth[282]).
- Digital data documentation.
- Survey documentation (size of grids, traverse spacing, and instruments used).
- A list of all file names with an explanation of codes used in file names.
- Data storage (format of data, how do the files fit together, hardware, operating system and software (version) used to create them).
- Data analysis (filters applied to the data and images with interpretation drawings).

[281] Data processing is further explained in chapter III.
[282] Chart Datum (CD), Ordnance Newlyn (ODN), or Vertical Offshore Reference Frames (VORF).

- Description of known errors or areas of weakness in the data.

There is currently no set requirement to archive and disseminate marine geophysical data for archaeological purposes. There should be particular interest in data storage and availability. HE should have unprocessed and processed data from all the wrecks that have been surveyed, to facilitate future research using data collected in the past.

The assessment of the methods used to record, monitor and research the *Hazardous Prize* revealed important information about the site formation process of the site. However, it also revealed the gaps in knowledge about the wreck. Leaving an opportunity to contribute to recording the decaying process on the wreck with an annual multi-image photogrammetry survey.

5.6 Results

The results are presented in pre-disturbance and post-disturbance surveys, demonstrating comparative results by emphasising the importance of both research stages. This approach offers further possibilities for understanding the site dynamics and its direct impact on the wreck. The analysis considers the effects of both the *extracting filters* (sections 4.1.1-4.15) and the *scrambling devices* (4.2.3 and 4.2.4) on macro, meso and intra-site levels.

5.6.1 Pre-disturbance Surveys

5.6.2 Multi-beam Eco Sound (MBES) Time-series

The best method to understand sediment mobility on a macro and mesoscale is through a tailored geophysical survey, specifically with a repetitive high-resolution MBES. This method has been demonstrated to be cost-effective and adequate to understand site dynamics as well as sea-bed movement (Astley 2016; Bull et al. 2005; Dix et al. 2006; Gutowski et al. 2008; Ortiz-Vázquez 2013; PAS 2017; Plets et al. 2009, 2013; Quinn et al. 1998; Quinn, Bull, Dix, et al. 1997).

The available data sets for *Hazardous Prize* had different set-ups and resolutions that limit our capacity to understand sediment migration (Table 24).

Hazardous							
Date	**Survey**	**Equipment**	**Frequency/ Resolution**	**Software Process**	**Format / RAW**	**Gridded Resolution/ Positioning**	**Datum**
02/07/2014	WA	R2Sonic 2024	455 kHz	HyPack Navigation and QINsy	HSX /.xyz	.50cm D-GPS	WGS84 30N/ CD
07/10/2013	CCO	Kongsberg EM3002D, EM2040D	200 /400 kHz	Uncertain	.xyz ASCII	1m	OSGB36/ ODN
29/09/2003	WA /ALSF	Reson SeaBat 8125 multibeam	455 kHz	HyPack Navigation and QINsy	.txt	.50cm RTK	WGS-84 / CD
29/09/2002	ADU	Reson SeaBat 8125 multibeam	455 kHz	-	.pts	.50cm D-GPS	WGS-84 / CD

Table 24. The table presents all standard used the MBES surveys.

High-resolution observation of the seabed and its mobility is an area of research with increasing interest in understanding and monitoring underwater cultural heritage. MBES surveys create thousands of survey points to present a full 3D model based on measuring acoustic travel time through the water column[283]. By covering the same area systematically with repeated surveys, it is possible to map sediment wave migrations and present a full 4D[284] model.

Up until now, *Hazardous* has relied on single geometrical readings that only partially represent the complexity of local hydrodynamics and partial sediment wave modifications. Nonetheless, by using the available MBES data sets it was possible to create a time-lapse with different time intervals (Figure 48):

- A) Intra-annual, subtracting MBES WA (2003) minus ADU (2002).
- B) Intra-annual, subtracting MBES CCO (2013) minus WA (2003).
- C) Cuasi-decadal, subtracting MBES WA (2014) minus WA (2003).

This was possible by subtracting the re-processed raster[285] datasets from different years to measure sediment change using a Spatial Analysis tool on ArcMap 10.5® (ESRI 2018c)(Figure 49).

[283] Further explained in Chapter III section 3.3.4
[284] Three dimensional (3D) + time = 4D.
[285] Spatial data model that defines space as an array of equally sized cells arranged in rows and columns, and composed of single or multiple bands. Each cell contains an

On figure 50, it is possible to see the different resolutions in the MBES surveys used for the mesoscale analysis of site dynamics: A) ADU 2002 (50 cm), B) WA 2003 (50 cm), C) CCO 2013 (1m), and D WA 2014 (50 cm).

The analysis of the time-lapse series created by the MBES datasets (Figure 49), is consistent with the *in situ* observations from the WHPPG team (see table 19), summarised by HWTMA (2006) (Figure 44). The intra-annual analysis (Figure 49 (A)), which was created by subtracting WA (2003) minus ADU (2002), presents a clear erosion area to the south of the main wreck site. In addition to a smaller area of erosion between the cannonball mount and guns. This same pattern is observed ten years later, on another intra-annual analysis (Figure 49 (B)) using CCO (2013) and comparing to the WA (2014) survey. However, the erosion area seems to be more extensive in an East-West direction. The most representative time-series period for this study was the quasi-decadal (Figure 49 (C)) period using WA (2003) and WA (2014) surveys. This was created with the two most consistent surveys carried out on *Hazardous,* using similar parameters, equipment and resolution (50 cm). The structure lost during 1997 (Grant 1997; Johnston 2014), lies within the area identified with most erosion (Figure 49 (C)), from 2003 to 2014. This shows a tendency of the seabed dynamics on the mesoscale. This erosion extended creating scouring patterns on both the East and West sides of the main structure remains of the wreck. This pattern of erosion has been further observed *in situ* by the author of this thesis as part of the WHPPG up to 2018. The resolution of the MBES data sets is sufficient to understand the site erosion. However, to be able to correlate directly these observations with the remaning structural features of the wreck, it is necessary to use other techniques, such as multi-image photogrammetry.

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attribute value and location coordinates. Unlike a vector structure, which stores coordinates explicitly, raster coordinates are contained in the ordering of the matrix. Groups of cells that share the same value represent the same type of geographic feature.

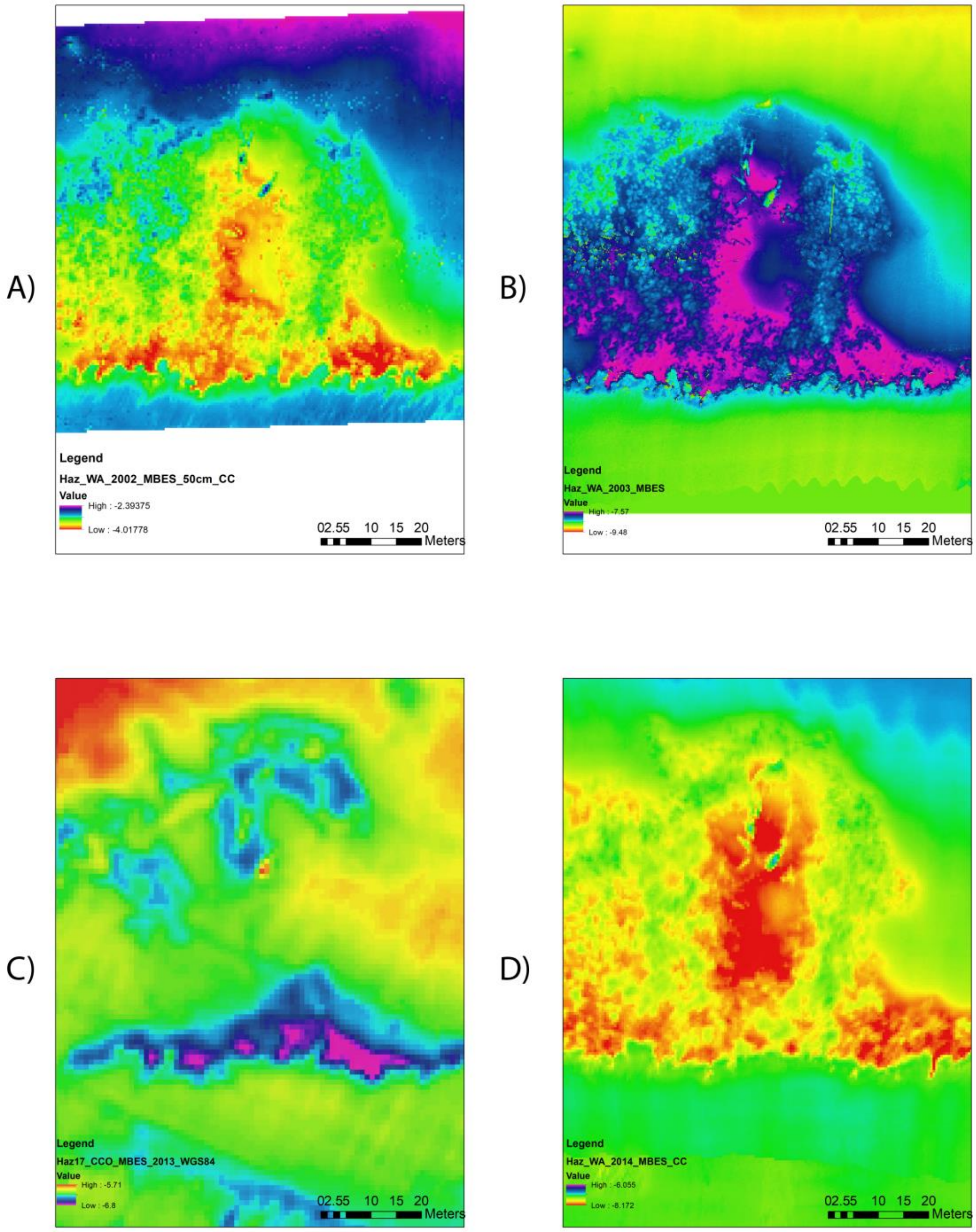

Figure 48. The figure shows MBES surveys A) ADU 2002, B) WA 2003, C) CCO 2013, and D) WA 2014.

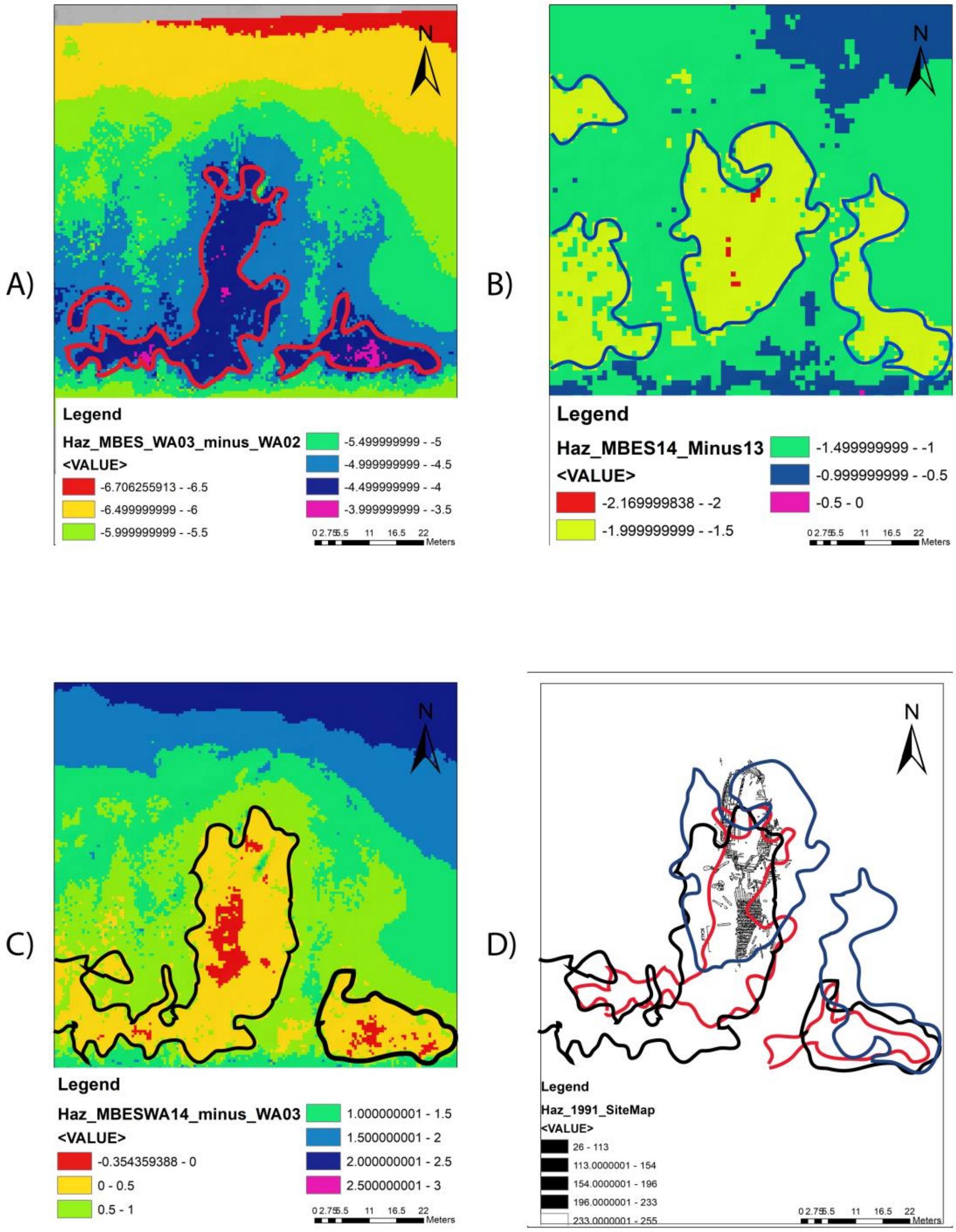

Figure 49. The Figure shows the MBES minus calculation in ArcMap10.5 ®. Intra-annual A) MBES WA 2003 Minus ADU 2002. Decadal B) MBES CCO 2013 Minus WA 2003. Quasi-decadal C) MBES WA 2014 Minus WA 2003. Site plan made in 1986-1990 by Owen (1991)**, that was digitized and geo-referenced by the author of this thesis.**

5.6.3 Multi-image Photogrammetry (MIP) Time-series

At an intra-site level, the best method would be Multi-image Photogrammetry (MIP) survey, and in particular Close-range Photogrammetry (CRP). This technique allows for the creation of 3D models, Digital Elevation Models (DEM) and ortho-rectified images[286]. It is important to create an extensive Ground Control Network (GCN), to guarantee accuracy and have the possibility to compare different surveys. The GCN was geo-referenced, using recognisable features in the MBES surveys, giving x (easting), y (northing) and z value (depth), for each point in WGS 84 Zone 30N.
The main challenge with the *Hazardous* site is the poor visibility throughout the year, with improvement during the summer months when the weather is benign. Strong south-westerly winds, stormy weather and big swells stir up the seabed worsening the visibility to less than a metre. Therefore, timing the dive to have extensive coverage of the site is critical and is preferably done during the summer.

In 2017, the WHPPG[287] had planned a targeted excavation on a section of the wreck that had a high potential of finding the archaeological material, identified by the over thirty years of experience from the project. Before the excavation started, a pre-disturbance survey was proposed as part of this thesis' project. Fortunately, during a few days in July 2017, diving conditions were exceptionally good with +/- 4 metres visibility that allowed covering 275.4 m^2 of the wreck site (Figure 50). During 2018, the visibility conditions, 1/1.5 m restricted the coverage. Although the team set out to cover the same area as the previous year and extend the survey to the South, including more guns, only 84.38 m^2 were successfully surveyed (Figure 50). However, the overlapping areas allowed a detailed analysis of an intra-annual survey that revealed the rapid decay of the wreck, and the loss of structural remains on *Hazardous* (Figure 51).

Even though the MIP time-series is relatively short (one year), and it has a limited coverage area (60.34484 m^2), it shows the rapid decay of the site, due to biological, chemical and physical erosion (Figure 51). The annual interval shows mainly marine growth on the guns, with little change in the surrounding seabed and structural timbers that have eroded away and disappeared. During the survey of 2018, it was necessary to add more markers as Ground Control Points (GCP), because some of the markers had vanished from the site. It was also necessary to adjust the nails on the

[286] Further detail of photogrammetry in section found in 3.3.4, Chapter III.
[287] Warship Hazardous Prize Project Group (WHPPG)

remaining control points as they had lost 30 to 50 mm of a wooden structure that is visible on the time-series (Fig 53).

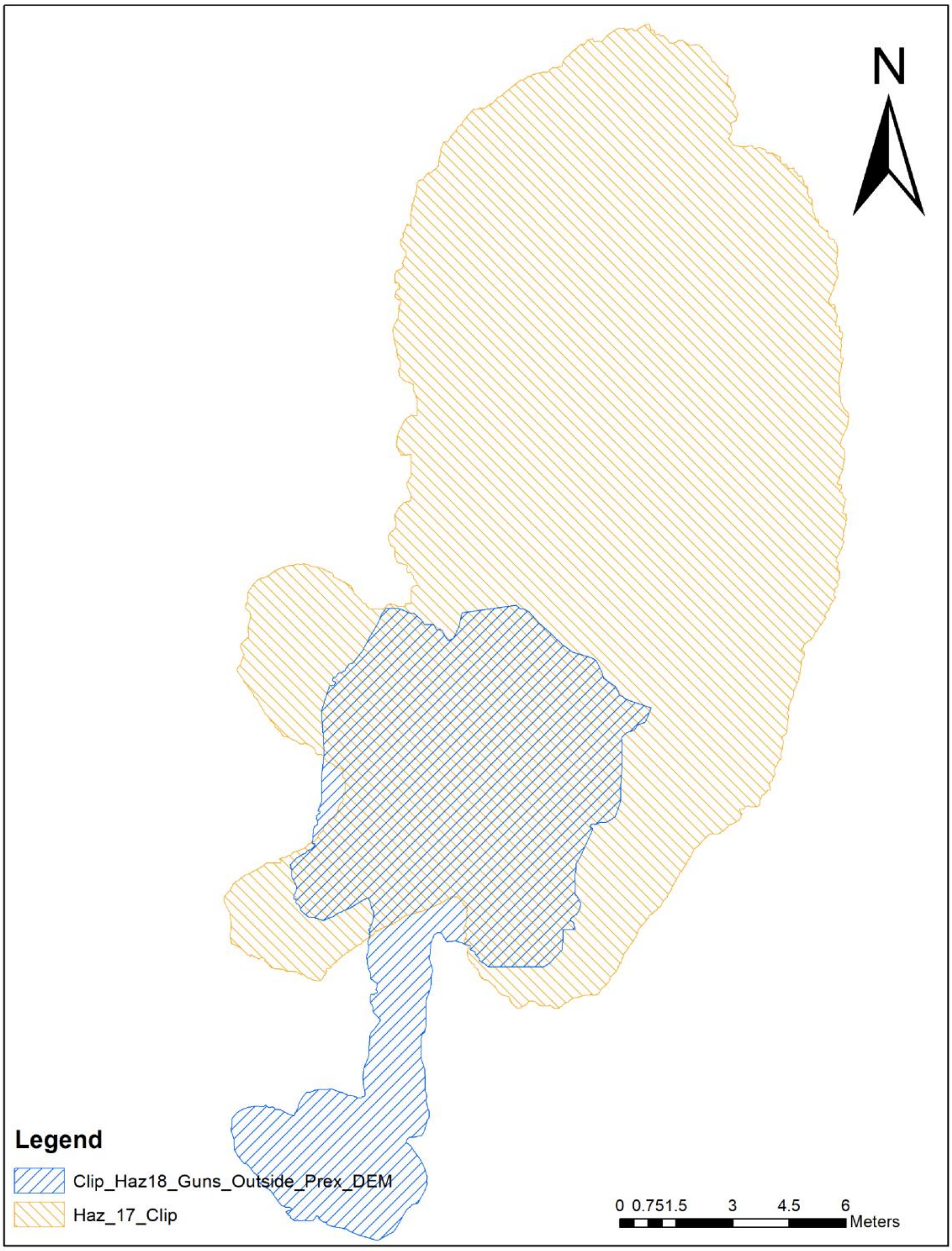

Figure 50. The 2017 survey covered 275.4 m^2 and the 2018 survey covered 84.382699 m^2. The author of this thesis made the image in ArcMap 10.5®.

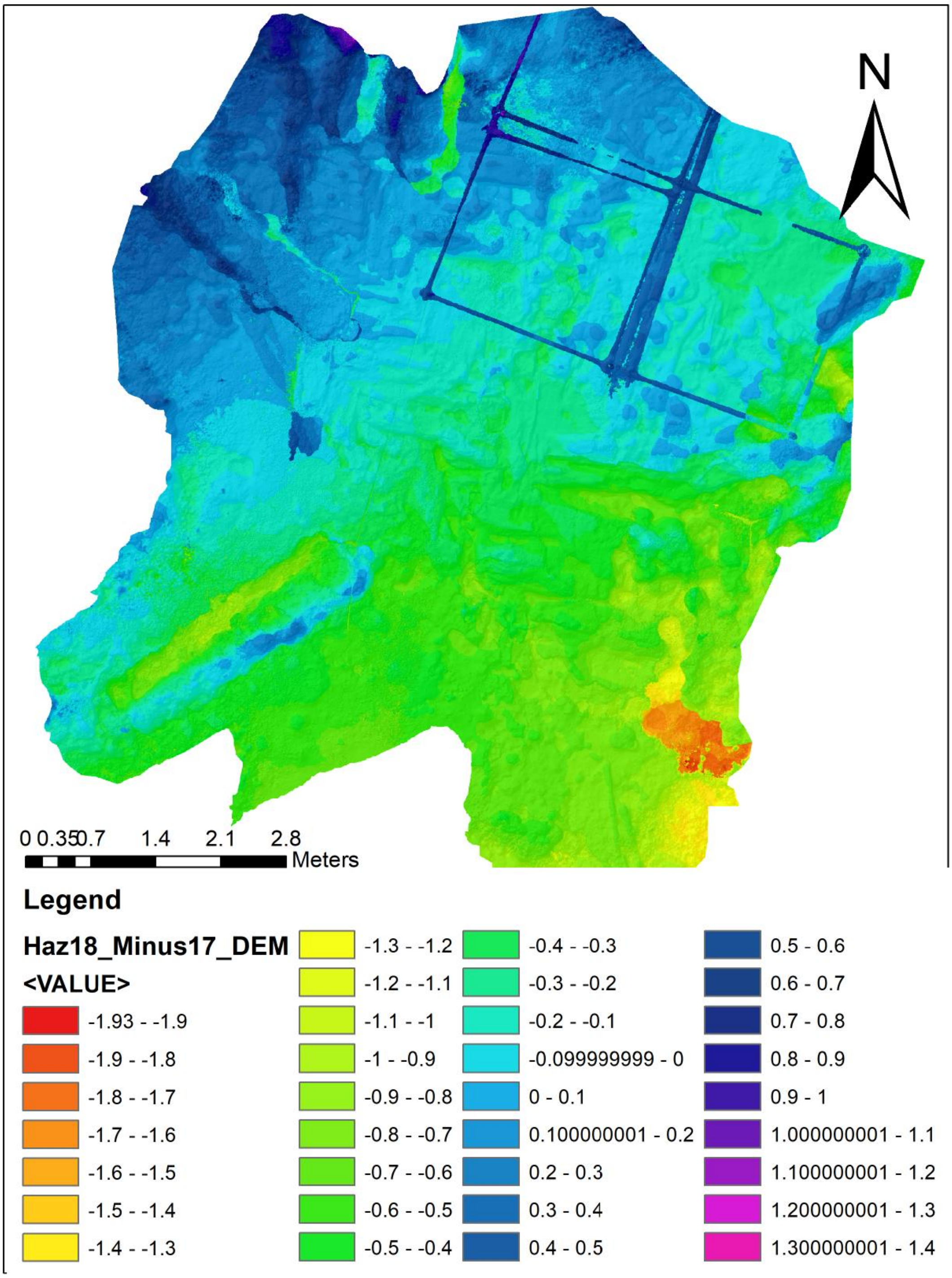

Figure 51. The figure presents a minus calculation in ArcMap10.5 ®. The intra-annual spatial analysis that compared DEM's from 2017 and 2018, showing changes in the main area of the wreck site. The author of this thesis created the map.

5.6.4 Excavation in 2017 and 2018

In 2016, the WHPPG was awarded a licence by Historic England to excavate the *Hazardous* wreck site. The excavation was concerned with understanding the mobility of the seabed and the accelerated erosion around the wreck. This has had a major impact on the wreck structure as well as numerous artefacts have become exposed (barrels, rigging blocks, gun carriage axels, ordnance, buckles and other personal items) (Pascoe Archaeology 2018a)[288].

The WHPPG started excavating in the summer of 2017, aiming to record the ships' structural remains as well as the precise location of artefacts found during the excavation. The excavation continued during the summer of 2018, extending the archaeological record of the ship's structure, including areas that have not been revealed previously.

As an intrinsic part of the excavation (2017-2018), this project was concerned with the recording monitoring and integration of data to contribute to the understanding of the site formation processes of the wreck site. The historical records mention the *Hazardous* was blown across the eastern Solent. Lieutenant John Hares aimed for the shore in Brackelsham Bay attempting to save the crew and vessel before she ran aground on the reef (PRO ADM 95/15 1706). On the wreck, the bow is pointing towards the beach with a northerly direction. The WHPPG's previous work and interpretation of the *Hazardous* clearly identified the forepeak with possible breast-hooks (strengthening pieces for the bow). Additionally, the WHPPG had identified that a large portion of the buried section of the wreck was the port side, confirmed by a series of beams supporting the gun-deck (Owen 1991:325–26).

The keel was not identified until 2017 when the erosion of the site had uncovered a section that was not visible since the discovery of the site in 1977. The identification of the keel was key for a better understanding of the site formation process of *Hazardous* (Figure 52 and Figure 53). The rest of the structural features became much clearer with the certainty of not having a coherent starboard structure (Figure 54, Figure 55 and Figure 56). The *Hazardous* wreck site shows a great number of similarities with the *Invincible* presented in chapter VII. The port side structure was better preserved probably because she keeled on that side, and the sediments buried it. Whereas the starboard structure was broken-up and scattered due to the prevailing winds and waves coming from a south-easterly direction. The *Hazardous* wreck site has a maximum tidal current of 0.5 knots, which is relatively weak. However, the shallow waters create a high-energy environment, transferring energy from the storms (wind, waves, swell and fetch) to the seabed. The storms have a major impact on the wreck,

[288] Video on Pascoe Archaeology: website https://pascoe-archaeology.com/portfolio/the-hazardous/

as this increases the energy in the environment considerably, scattering artefacts that lie on the seabed across the site.

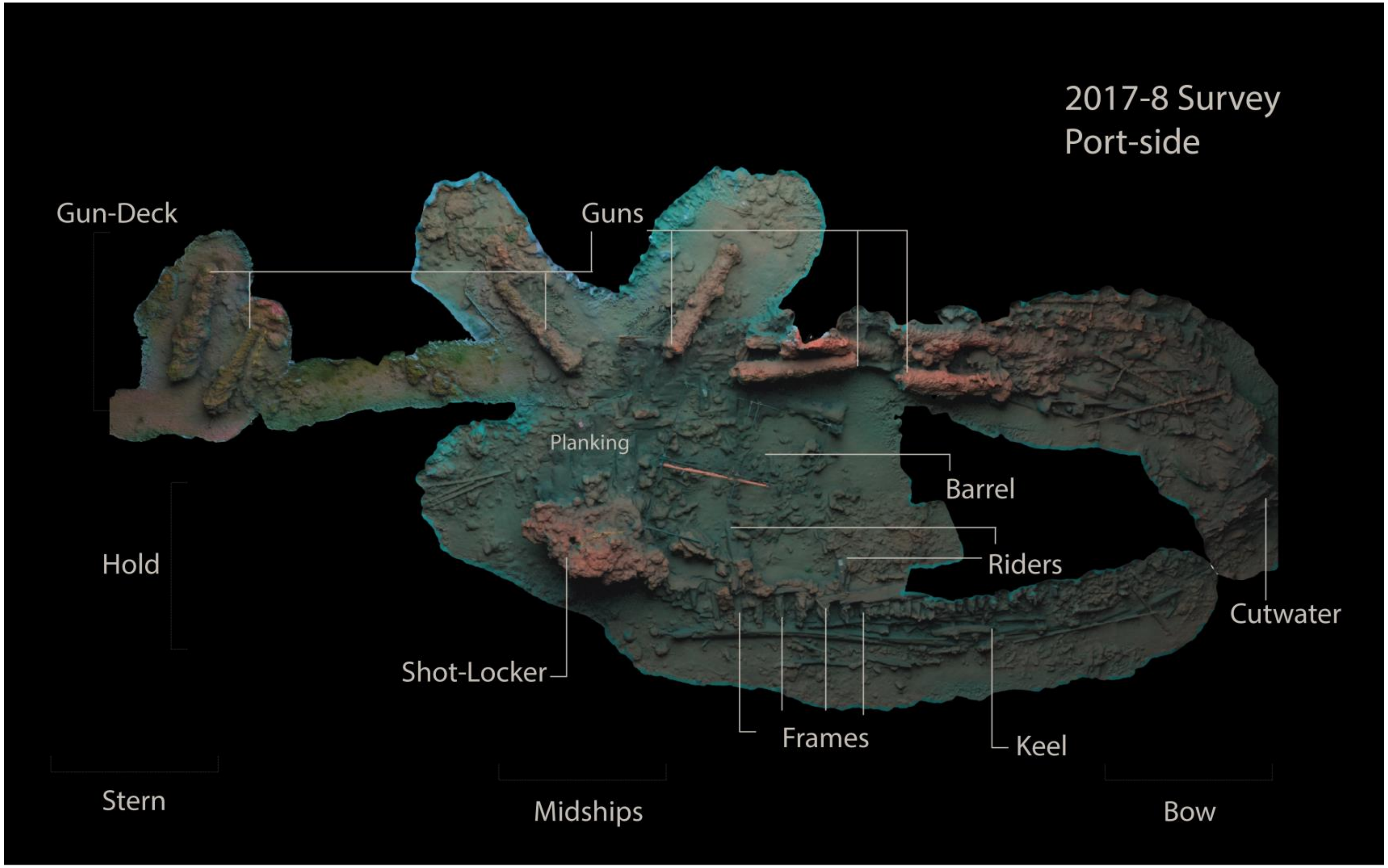

Figure 52. The author of this thesis did the photogrammetry survey and processed it on Agisoft Metashape Pro v1.5 ®. The image was rendered in 3dsMax®.

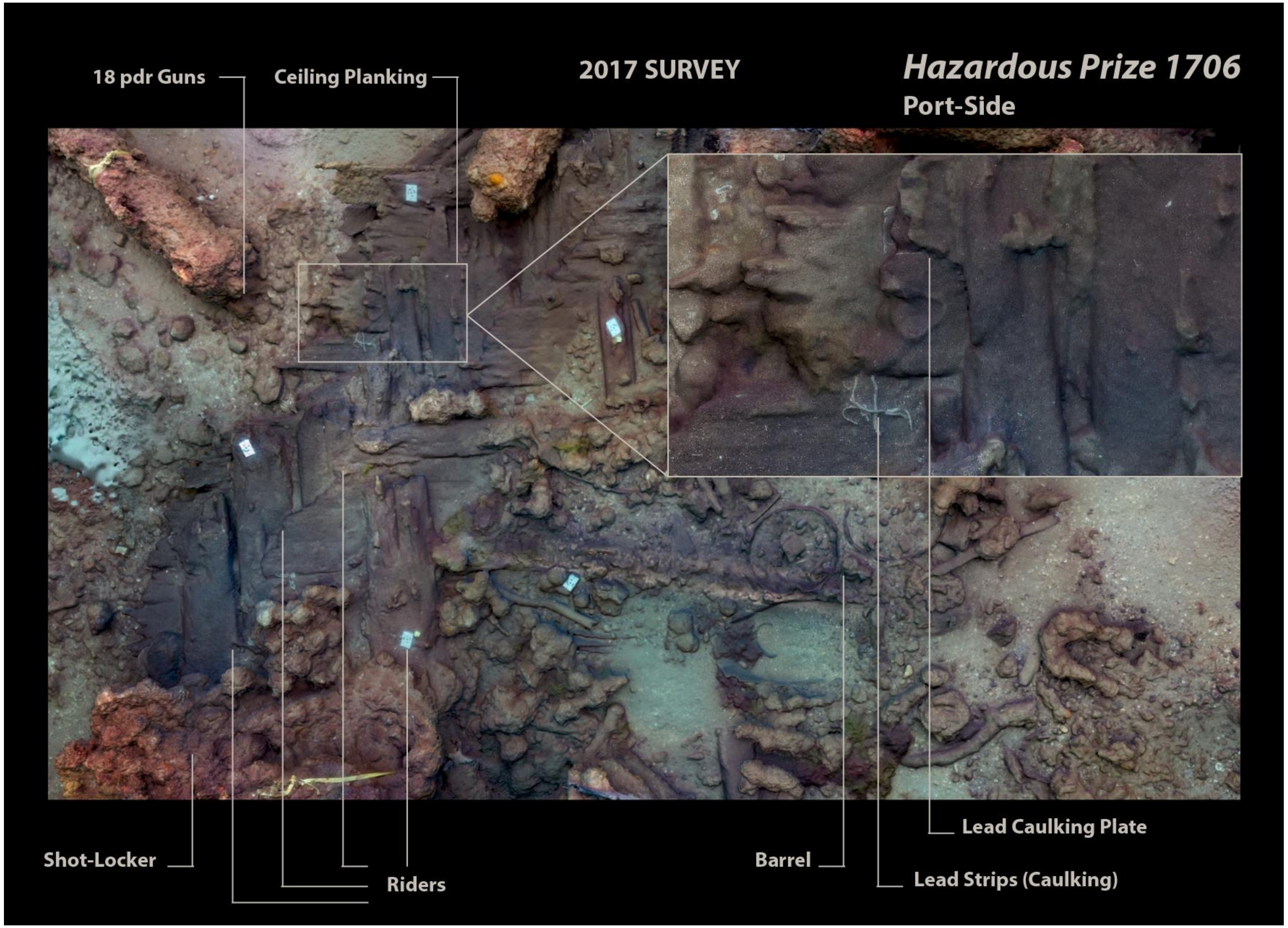

Figure 53. The author of this thesis did the photogrammetry survey and processed it on Agisoft Metashape Pro v1.5 ®. The image was rendered in 3dsMax®.

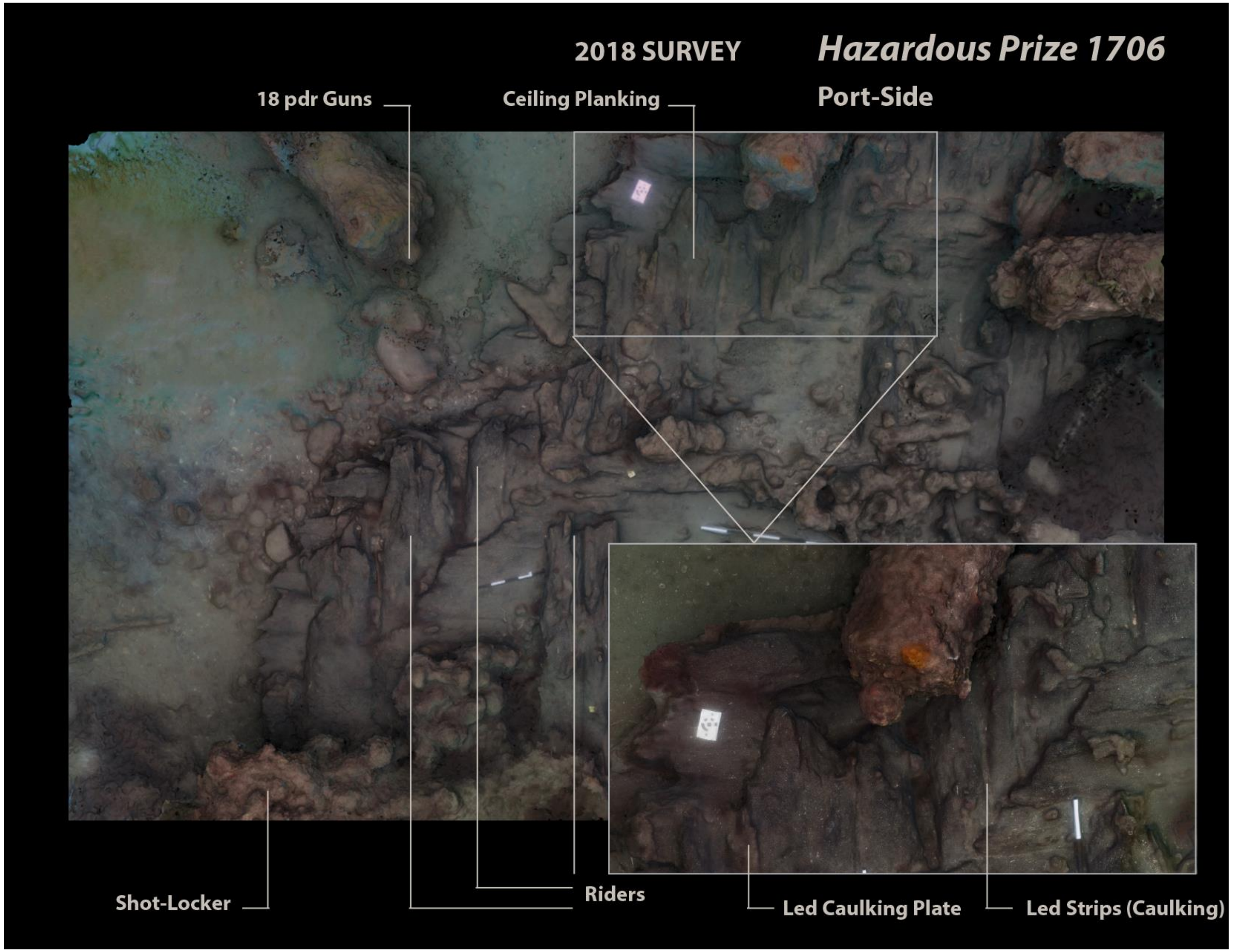

Figure 54. The author of this thesis did the photogrammetry survey and processed it on Agisoft Metashape Pro v1.5 ®. The image was rendered in 3dsMax®.

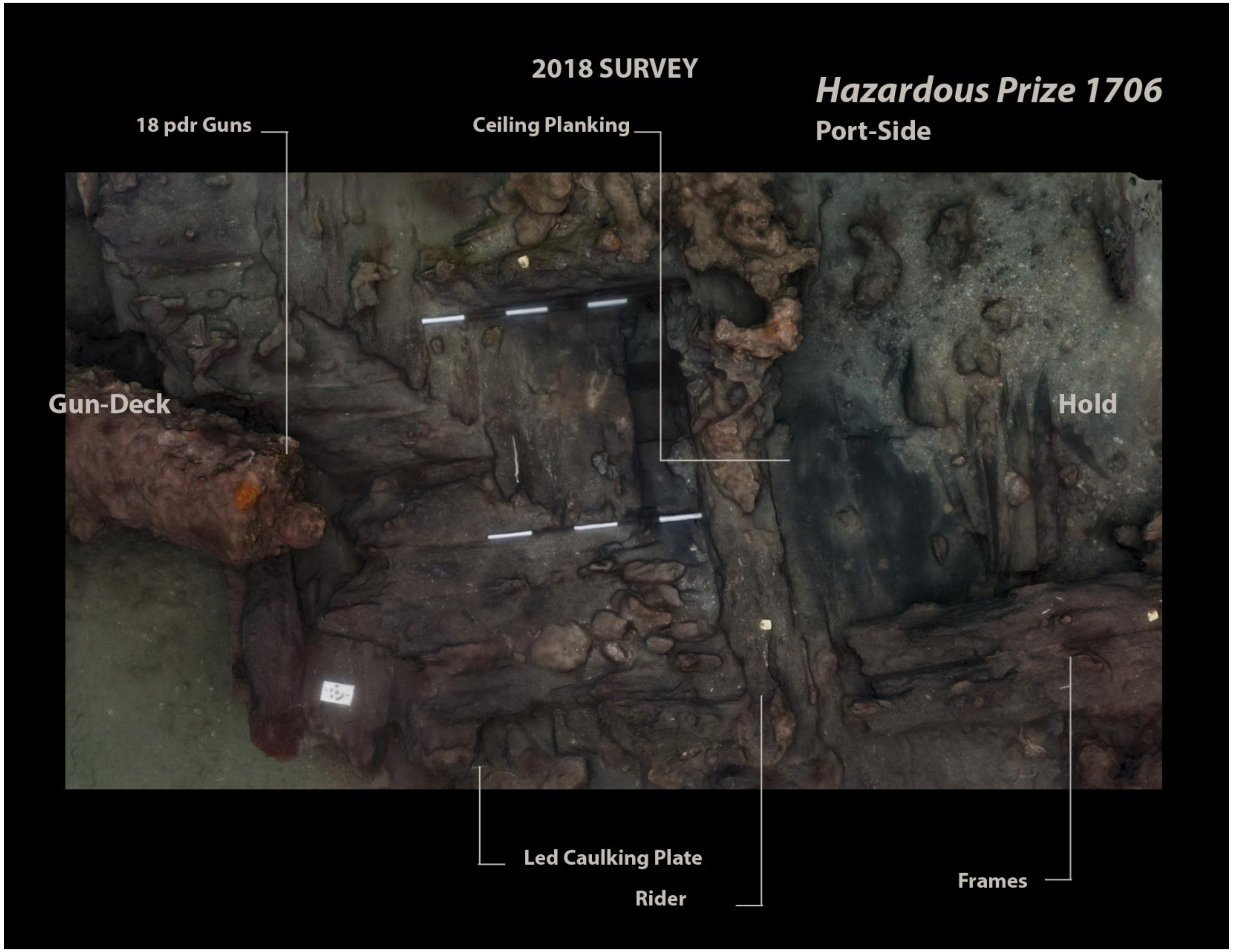

Figure 55. The author of this thesis did the photogrammetry survey and processed it on Agisoft Metashape Pro v1.5 ®. The image was rendered in 3dsMax®.

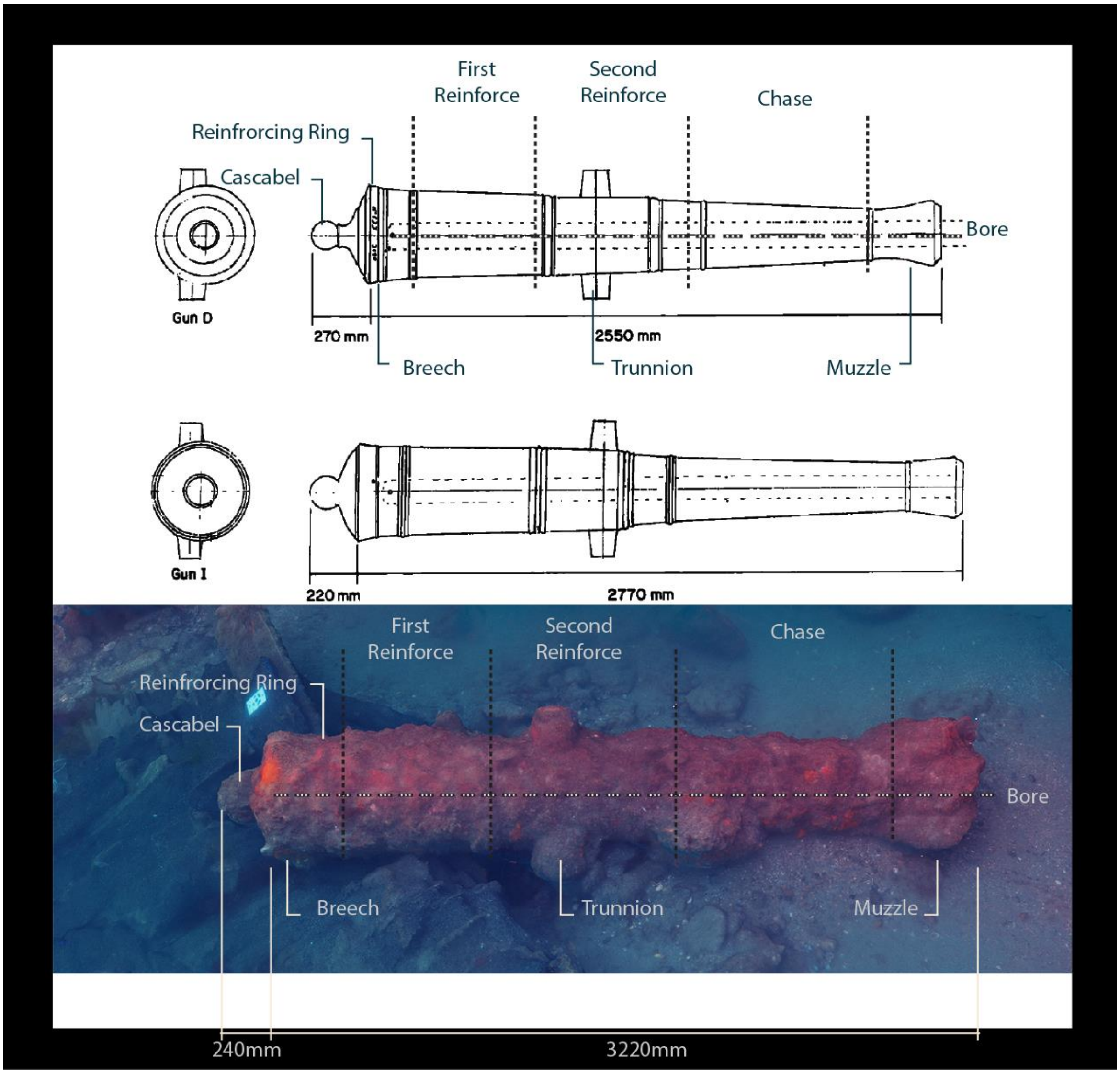

Figure 56. A detailed survey of one of the guns on the seabed compared with the guns that were raised in 1988 by the Hazardous Project (Owen 1988:330)[289]**. The author of this thesis did the photogrammetry survey and processed it on Agisoft Metashape Pro v1.5 ®.**

5.7 Discussion

The *Hazardous* wreck presented the challenge of contributing to a project with extensive research on the site. The first task was to make a critical evaluation of the available data that has been collected for over 30 years of work. During this stage, it was possible to identify the knowledge gaps in understanding the site formation processes of the wreck and contribute with new information. Specifically, integrating

289 These were treated unsuccessfully using electrolysis at the Conservation Department of Portsmouth City Museum. However, detailed photographs were taken and equally detailed drawings were made at the time (Owen 1988: 330).

high-resolution recording techniques that allowed an evaluation of previous research and a better understanding of environmental dynamics.

A key moment of this project was locating and identifying the remains of the keel during the continued visits on site (Figure 52). For the first time, we could say with certainty that the remaining coherent structure was the port side of the wreck, from amidships towards the bow. This immediately led to several conclusions regarding the remaining structure. Firstly, the stern section had disappeared entirely, although a scour mark shows the area where it probably laid. Secondly, the starboard side had been broken up and scattered. Additionally, some of the remains of the starboard side could be found in the surrounding gulleys of the reef, although this needs to be further investigated, and it might be difficult to identify these structural remains.
The photogrammetry survey in 2017 allowed having a complete evaluation of the extent of the coherent structure in only a couple of dives (Figure 57). The use of multiple-image photogrammetry allowed mapping an area of 275.4 m^2, which otherwise would have taken several weeks or months to record with traditional methods (DSM). Furthermore, the establishment of a ground control network made it possible to verify the accuracy of the survey and acquire comparable data sets during 2018.

The integrated methodology of this thesis presents for the first time a qualitative and quantitative comparison that can fully illustrate the rapid decay of the site (Figure 50, Figure 51, Figure 52, Figure 53 and Figure 54). The 4D time-lapse of MBES surveys allows tracing the seabed movement, with areas of accretion and erosion across the site (Figure 49). The comparative DEMs from the 2017 and 2018 MIP surveys, facilitates the quantification of site erosion of an extensive area, with evidence of loss of sediment and timber degradation (Figure 51). Furthermore, the newly collected data allows conferring with previous survey plans, answering crucial questions about the wrecks' structure and the post-wrecking process. Although it also raises more questions, such as: where is the remaining starboard side? Alternatively, is there a remaining starboard side? These questions can only be addressed with an extensive high-resolution survey that combines MBES and multi-image photogrammetry. An extensive excavation of the coherent portside structure can only solve other questions about construction techniques in the 17th century before it is too late and the high-energy environment erodes and destroys what is remaining of the site. The extensive excavation would also reveal micro-stratigraphy within the wreck that would offer new insight into the sedimentation process on an intra-site scale.

The site offers a great comparative case study to the *Invincible* (Chapter VIII), due to similarities in their remaining coherent structure. Both ships where British man-of-war vessels, captured from the French, that keeled over on their port side and lost the starboard side to physical erosion that is mainly dominated by storm action.

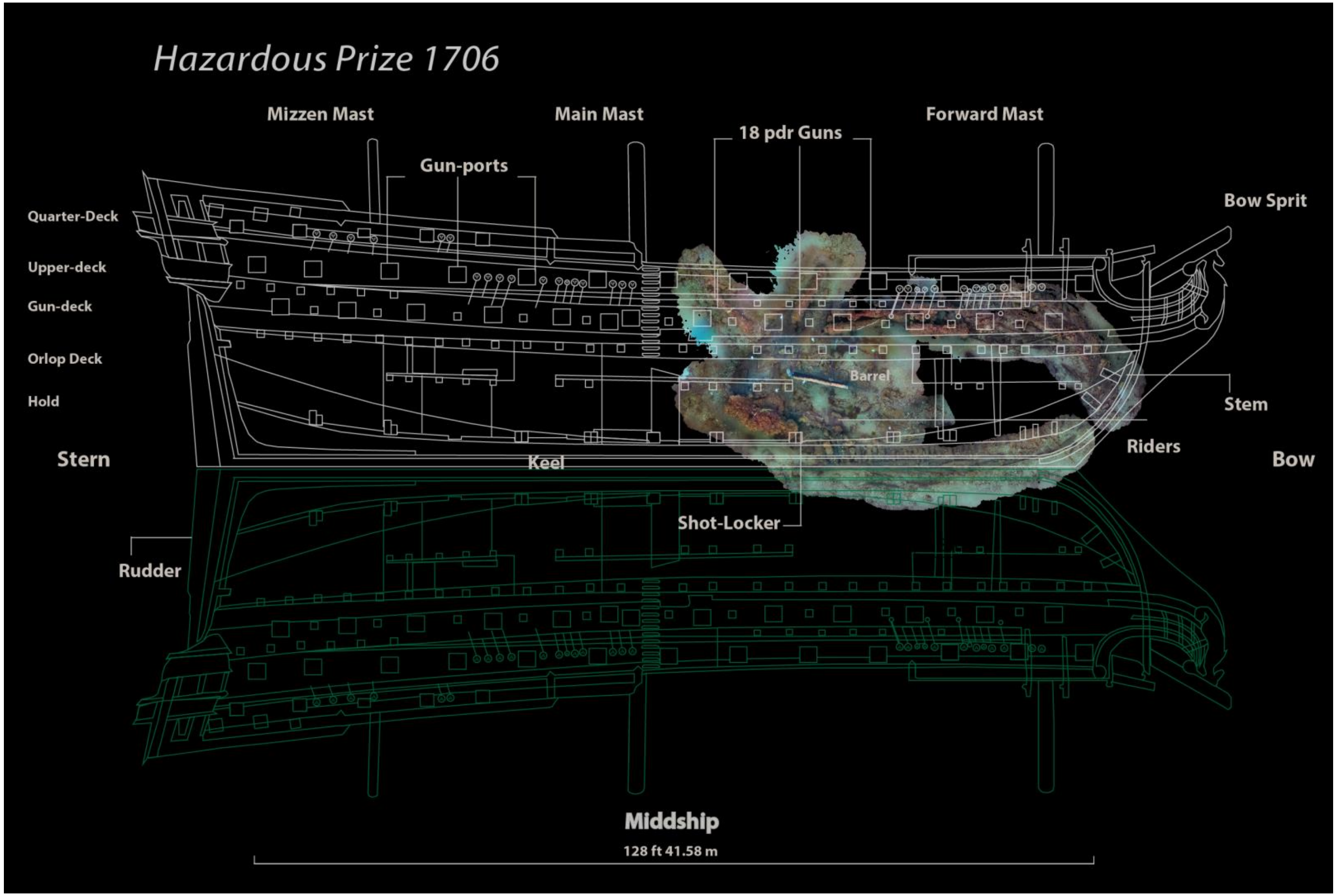

Figure 57. The image shows both port (white) and starboard (green) sides based on the *Hazardous* ship-lines. The orthophoto in the background shows the part of the wreck that was surveyed. The author of this thesis created the image.

5.8 Conclusions

The *Hazardous Prize* is an example of a shallow water wreck in a high-energy environment in British waters that is dominated by wind, waves and storm action. The wreck lies in a gulley running in a North-South direction of a reef. This leaves the *Hazardous* vulnerable to the dominating tide and wind patterns of Bracklesham Bay (Fig. 60). The *Hazardous* is a high-energy environment with a coherent ship structure and some artefacts (H2aF[290]).

The integrated methodology presented in this chapter offers a 4D analysis of the site formation processes on *Hazardous* on a multiple-scale. The critical analysis of the sources revealed both strengths and weaknesses of the accuracy and resolution of recording techniques previously used on the wreck. On a macro-scale, Bracklesham Bay is a high-energy environment due to the depth and the extensive exposed area subject to storm action (waves and wind) and tidal cycles. On a mesoscale, the wreck has been subject to sediment erosion that has a direct impact on the structural remains, meticulously recorded by the WHPPG (Figure 49). The environmental dynamics show a strong correlation between the loss of large portions of the structure in the last 20 years (Figure 49 and Figure 51). The MBES time-lapse clearly demonstrates areas of erosion and accretion on the *Hazardous*, creating a predictive model of continued erosion on localised areas of the site. Nonetheless, consistent high-resolution MBES (0.20 m resolution) would quantify these seabed movements[291] with higher precision and accuracy. The precision of a predictive model would have a direct impact on better-informed decisions for strategies of cultural heritage care and site management.

On intra-site scale observations the surveys conducted during the excavations of 2017 and 2018 present a qualitative (Figure 54 and Figure 55) and quantitative (Figure 51 and Figure 58) 4D model with an annual interval of the on-going erosion to the site. The evident erosion and gradual loss of coherent structure are consistent with the macro-scale approach that classifies this as a high-energy environment.

[290] According to the typology presented in chapter IV in section 4.3

[291] This is better demonstrated with site tailored MBES surveys on the *Rooswijk* in chapter VI or *Invicible* in chapter VII.

In sum, the methodology developed in this chapter has successfully combined previous work and newly acquired data to present a new interpretation of the formation process of *Hazardous Prize*. However, a better understanding of site dynamics and sediment migration could be achieved with site-tailored high-resolution remote sensing surveys integrating MBES and multi-image photogrammetry time-series on an annual basis.

5.9 Best Practice and Recommendations for Further Research

The *Hazardous Prize* wreck still has tremendous potential for further research. The presence of magnetic anomalies that match up with guns to the West of the *Hazardous* wreck is an interesting target for interpreting the wrecking process (Figure 59). These guns could have been jettisoned in an attempt to save the ship when she struck the reef. This potential impact site should be further surveyed with a high-resolution MBES and well as ground proving *in situ* observation followed by multi-image photogrammetry surveys (Figure 59). High-resolution site monitoring should also encourage an extensive photogrammetric survey on an annual basis, when the visibility allows it, to continue the time-series presented in this chapter.

On an intra-site scale, after identifying key structural elements of the wreck as part of the port side, further artefact distribution patterns could be identified to potentially indicate their shipboard associations. The wreck is a window to the 17th-century construction of French warships as well as repair and adaptions practised by the Royal Navy on captured ships. Further research should be carried out to understand the ship's methods of assemblage in detail before erosion devastates the site. Additionally, a virtual trail should be created to present the wreck to the public and promote the wreck site, generating interest on *Hazardous,* such as the ones done for *Rooswijk* and *Invincible* (HE et al. 2018; PAS & Artas Media 2016).

The *Hazardous* was considered as Heritage at Risk for English Heritage in 2014 (English Heritage 2014:97). Currently, she is not considered in that category by HE (2017b, 2017a). Based on the environmental dynamics, the *Hazardous* could be re-classified as "at Risk", as there is a visible deterioration of the site year after year. By putting it at risk more resources could be dedicated to record and monitor the wreck with adequate high-resolution remote sensing techniques. The wreck deserves more attention with a systematic geophysical assessment, particularly a high-resolution MBES, following a tailor-made methodology.

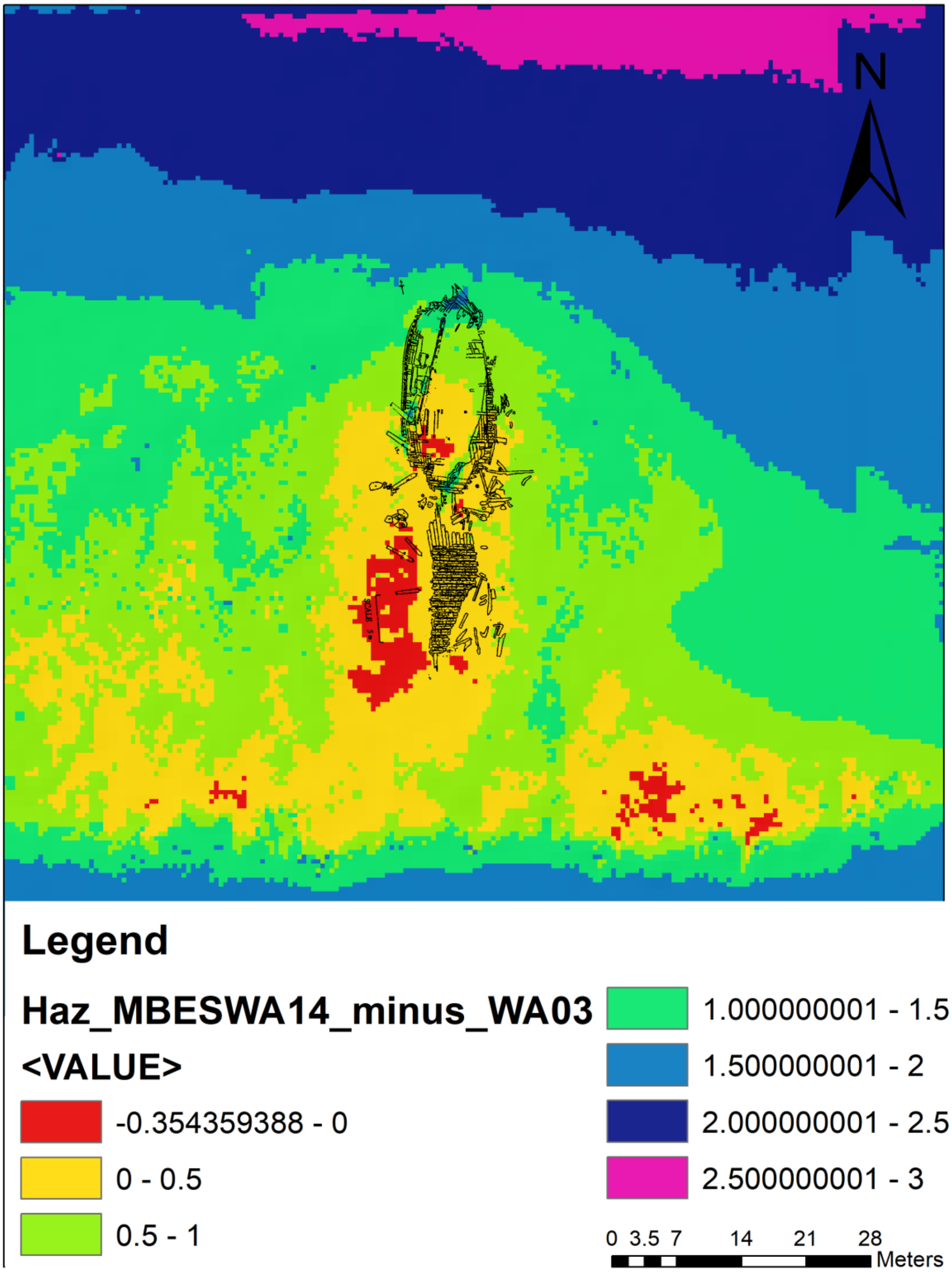

Figure 58. The figure shows a sediment migration and erosion visible with a quasi-decal time-lap of 11 years, based on WA 2033 and WA 2014 MBES surveys. The overlapping site plan from Owen (1990), shows the extent of the coherent record. The author of this thesis created the image in ArcMap 10.5®.

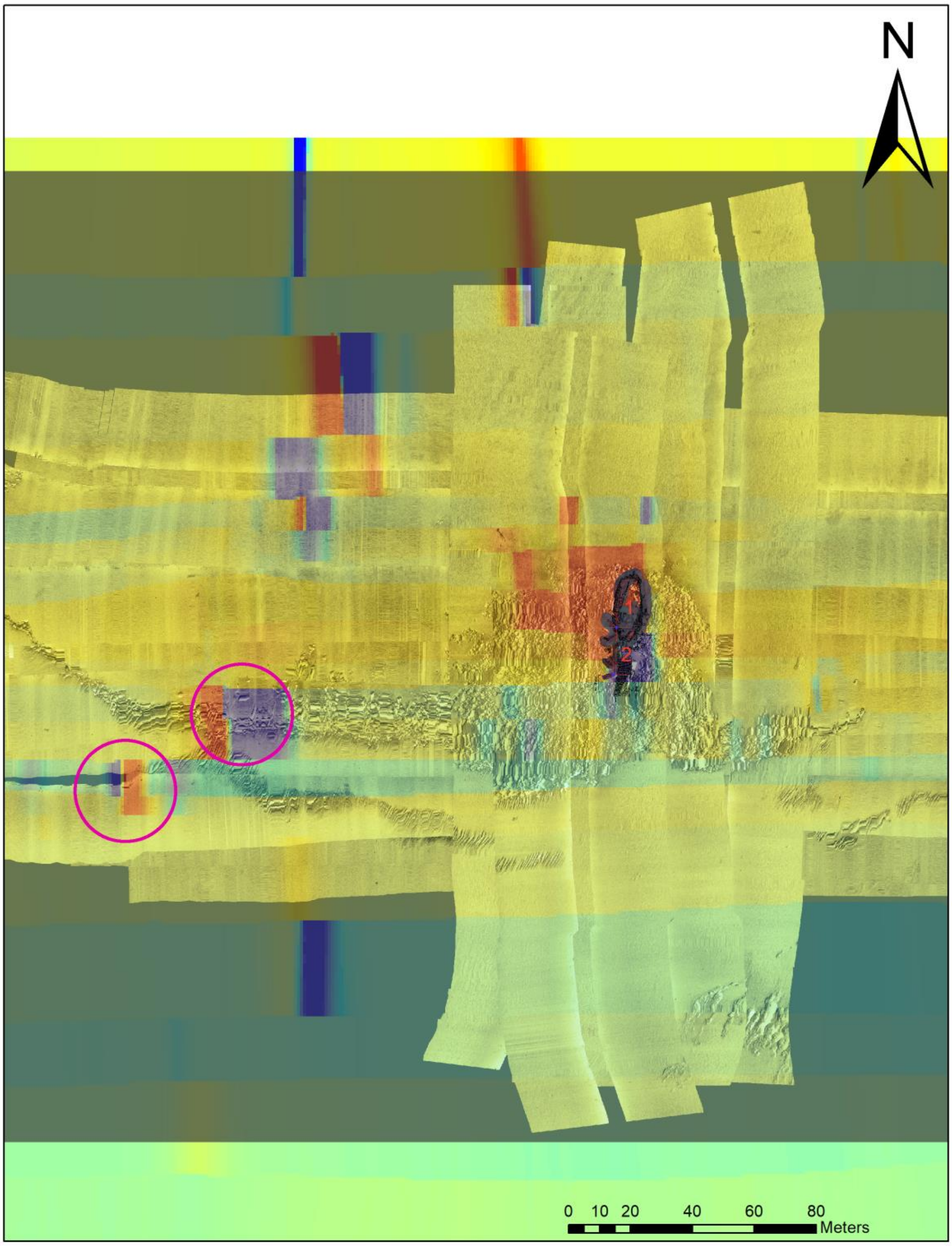

Figure 59. The figure shows a SSS survey with an overlapping MAG survey highlighting the magnetic anomalies, both datasets were acquired by WA in 2014. The main wreck, with coherent structure site, is shown with photogrammetry. The author of this thesis created the image in ArcMap 10.5®.

Chapter VI. VOC *Rooswijk* 1737-1740, Goodwin Sands in Kent

The *Rooswijk* was a Dutch East India Company merchant vessel that wrecked on the Goodwin Sands, off Kent, on 9th January 1740. She currently lies 8 miles offshore, to the southeast of the North Sands Head and northeast of the Kellet Gut. The *Rooswijk* was headed towards Batavia, modern-day Jakarta, in Indonesia, with a full cargo when she encountered a storm and never reached her destination.

6.1 Historical Background

The *Rooswijk* was built for the Dutch East India Company, VOC [292] chamber of Amsterdam in 1737. She was a "*retourschip"*" ("return-voyage ship"), a specific type of vessel that was designed to withstand the long voyages of 18 months to three years typically undertaken on route to Batavia in Southeast Asia (van Duivenvoorde 2015:17) (Figure 60). The ship had a large capacity for merchandise and would have been well-armed to defend its self during the journey (HE et al. 2018; MSDS Marine Ltd 2018; WA 2007).

The name *Rooswijk* probably refers to a former country estate in the Velsen region, in the Netherlands, which in 1735 came into the hands of a VOC merchant called Reynier Bouwens. Unfortunately, the vessels historical records are very limited. Primary sources are not easily accessed, as the archives are in the Netherlands and the documents are written in Dutch. However, there is a team of historians currently working on these sources but they are not available at the moment (Van Grondelle and Vermij 2018). So far, they have identified nineteen crew members from the last trip the *Rooswijk* did.

Luckily enough the VOC was a prosperous company that had a number of ships that sailed across the globe and are documented extensively. Other contemporary shipwrecks illustrate cargo, trade, practices, shipbuilding techniques, life on board, and site formation processes such as the *Amsterdam* 1748-1749 (Gawronski 1990; Marsden 1972), *Hollandia* 1742-1743 (Cowan et al. 1975; Gawronski et al. 1992), *Adelaar* 1722-1728 (Martin 2005), and *Vliegend Hert* 1729-1735 (Pol 1993). Other

[292] *Vereenigde Oostindische Compagnie* (VOC).

earlier examples include the *Kennemerland* 1661-*1664* (Dobbs and Price 1991; Forster and Higgs 1973; Muckelroy 1976a), *De Liefde* 1698-1711 (Bax and Martin 1974), *Batavia* 1628-1629 (van Duivenvoorde 2015; Van Duivenvoorde et al. 2013), *Zuiddorp* 1701-1712 (Van Duivenvoorde et al. 2013), and *Zeewijk* 1725-1727 (Ingelman - Sundberg 1977) (Table 25[293]). The *Rooswijk* is one of the eleven identified VOC shipwrecks that have been found in British waters (Table 25). Therefore, its study offers a great opportunity to understand more about VOC ships and the impact of the environment on the wreck.

	Name	Location	Date	Tonnage
1	*Adelaar*	Barra, Hebrides, UK	1728	810
2	*Amsterdam*	Hastings, UK	1748	1150
3	*Boot*	Salcombe, Prawle Point, UK	1738	650
4	*Hollandia*	Scilly Isles, UK	1743	1150
5	*Kampen (yacht)*	Isle of Wight, UK	1627	300
6	*Kennermerland*	Shetland Islands, UK	1664	950
7	*Lastdrager (flute)*	Shetland Islands, UK	1653	640
8	*Liefde (frigate)*	Shetland Islands, UK	1711	1009
9	*Prinses Maria*	Scilly Isles, UK	1686	1140
10	*Rooswijk*	Goodwin Sands, UK	1740	850
11	*Zeelelie*	Scilly Isles, UK	1795	1150

Table 25. The list shows VOC shipwrecks found in the UK. The list is based on Van Duivenvorde (2015:144–45).

[293] See full list in Appendix II, *Rooswijk* and shortlist

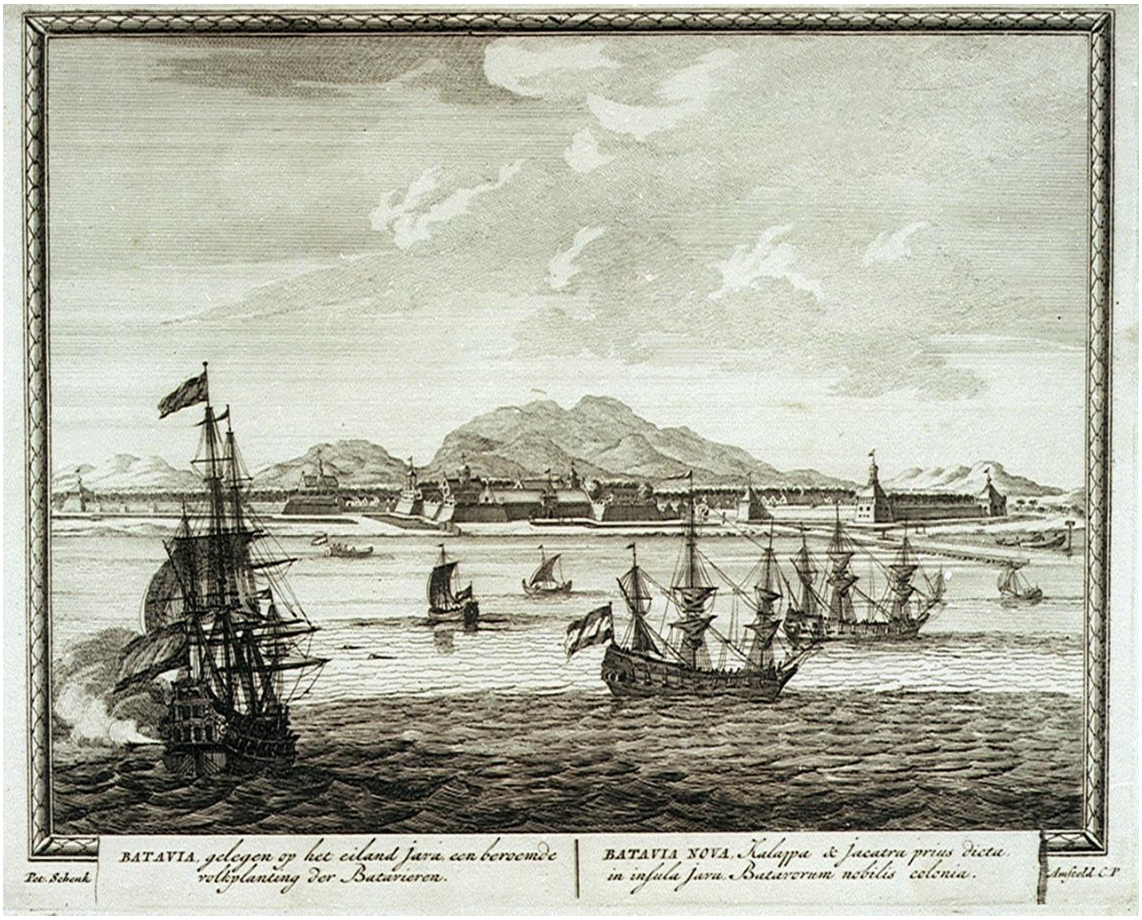

Figure 60. Batavia located on the island of Java, a famous settlement of the Batavians NMM (Schenk 1702)**.**

6.1.1 Ship Construction

The Rooswijk was built in 1737 for the Amsterdam Chamber at the VOC shipyard, Oostenburg in Amsterdam (Figure 61. The figure shows the several stages of shipbuilding taking part in Oostenburg shipyard, in Amsterdam. The original engraving is dated close to 1660 (Uknown 1725). The original engraving is held at the Rijksmuseum in Amsterdam.). She had 145ft (47.39 m)[294] of length, with 850 tons and a crew of 250-256. She was part of a large fleet of very successful Dutch merchant vessels known as *hekboot* (sternship), a mixture between a *fluit* (flute) and a *pinas* (pinnace) (Jong 2010:13). A *fluit*[295] is characterised as having a very rounded hull form at the bow, with the specific purpose of having a large cargo capacity to store trading

[294] Dutch foot or *voet*: 31.39465 cm (Digital Wetenshapshistorisch Centrum) Digital web Centre for the History of Science in the Low Countries 2018)

[295] The *fluit* was designed in such a way that the carrying capacity per crewmember was maximalised. They were lightly built, which made for a short lifespan, but which at the same time led to a cost price that was about 40% lower than elsewhere in Europe (Jong 2010:12).

goods (Eriksson 2014:10; Jong 2010:12; Unger 1978:44, 1995). On a *hekboot* The lower structure resembled a *fluit*, while the superstructure was designed after the *pinas*, a heavily built *fluit* with deeper draught, with greater sail-area per ton, again to increase speed (Hoving 1988:219; Unger 1978:38). The result was an increased carrying capacity and more generous accommodation for the crew[296] (Jong 2010:13).

The VOC chamber of Amsterdam commissioned several other *Hekboots* to be built in Oostenburg. More research is required on the classification of certain ships as *hekboots*, however, a short-list of ships provides an idea that there was a successful boat type for the VOC trading to southeast Asia (Table 26):

Name	**Date (Construction and loss)**
Van Alsem	1732-1739
Flora	1730-1737
's- Graveland	1722-1729
Groet	1732-1734
Hartenlust	1734-1753[297]
Horssen	1739-?
Kerkzicht	1735-1740
Knappenhof	1733-1754[298]
Leeuwrik	1741-1748
Noordwolfsbergen	1733-1747[299]
Pallas	1723-1747[300]
Phoenix	1739-?
Polanen	1737-1753
Reigersbroek	1726-1738
Stabroek	1722-1728
Susanna	1721-1737
Venenburg	1734-1740
Zorgwijk (renamed in 1732 in *Voorduin*)	1730-?

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[296] Only a small number were built by the chamber Amsterdam. *Hekboten* and large *fluits* (like the sugar fluit) were used both for return journeys and trips within Asia, while small *fluits* and *katschepen* (these ships being smaller than the smallest charter of *retourschepen*) usually stayed in Asia after their first outward journey (Jong 2010:13–14).

[297] Sold in Batavia

[298] *Idem*

[299] *Idem*

[300] *Idem*

Name	Date (Construction and loss)
Vreeland	1735-?
Vrijheid	1740-1748
Waterliet	1736-1742
Westerbeek	1722-1742

Table 26. The table shows possible *Hekboots*, built for the chamber of Amsterdam in a 20-year period. The table is based on ships parting going from Amsterdam to Batavia and back (Nijhoff 1979b, 1979a; Open Archives 2018b; De VOC site 2018).

Very little is known from the archaeological record on *hekboots* and the *Rooswijk* 1740 Project attempted to attend these lacunae. However, no coherent structure has been found to this date, apart from a few frames that seem to be part of the bottom of the ship. Shortly after the construction of the *Rooswijk* in 1737, the VOC went through a process of standardizing shipbuilding and equipment, with an annual production of three to five ships around 1750 (Gawronski 2017; de Jong 2016). The VOC possessed some of the largest preindustrial complexes in the Netherlands in its shipyards in Amsterdam and Middelburg (Gawronski, Jayasena, and Terhorst 2017; Kist 1990:50). The shipbuilding enterprise of the six chambers of the VOC was transformed over the years into one centralized large-scale technological system through the development of increasingly standardized designs and building methods (de Jong 2016:37). English master shipwright Charles Bentam, who was employed at the yard of the Amsterdam Admiralty, was asked to design three new charters of *retourschepen* for the VOC [301] (Figure 62 and Figure 63). From the plans and the model of the *retourschip* designed by Bentam (Bentam 1742b, 1742a), it is possible to have an idea of the lines of the *Rooswijk* (Figure 64).

[301] 150 ft length compared to 145 ft on *Rooswijk.*

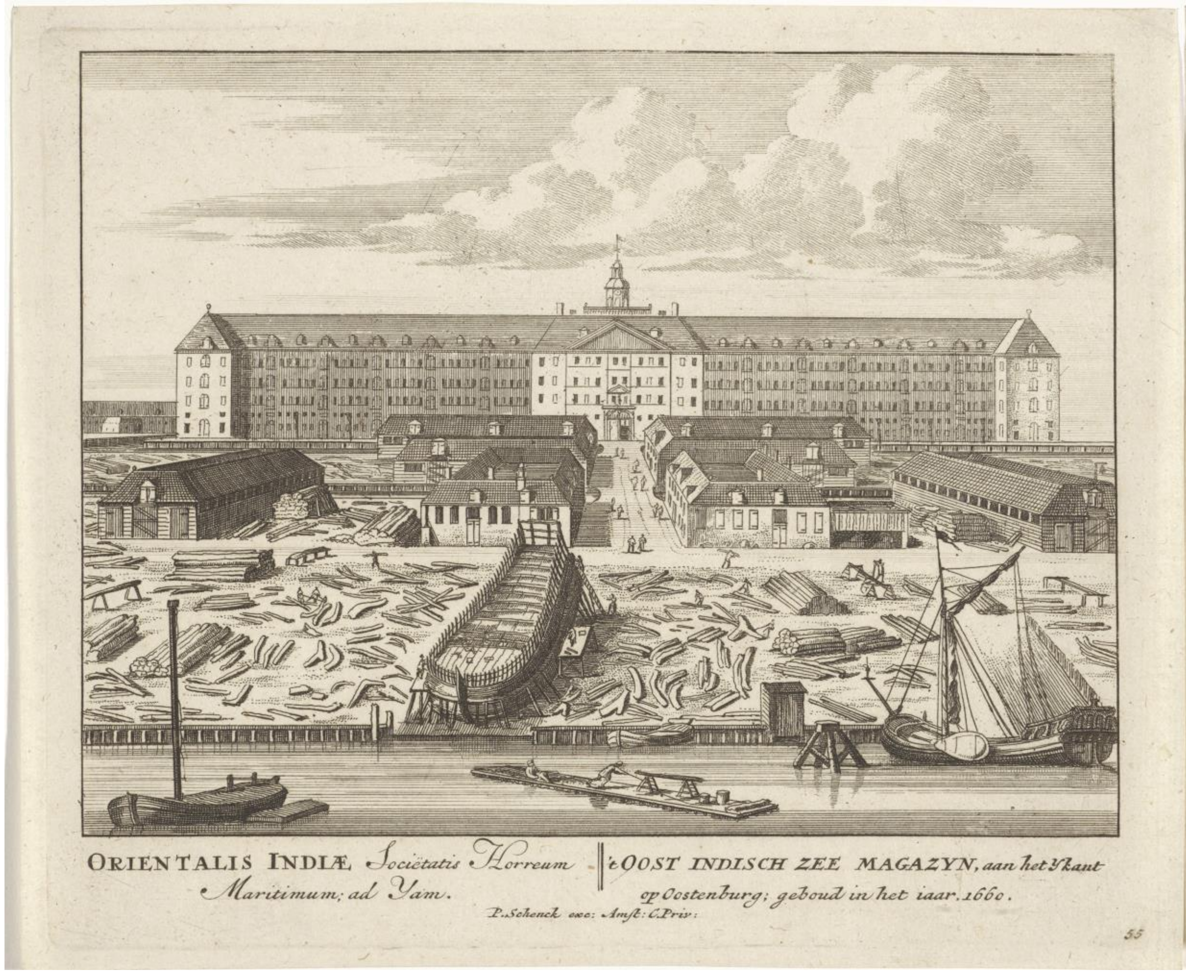

Figure 61. The figure shows the several stages of shipbuilding taking part in Oostenburg shipyard, in Amsterdam. The original engraving is dated close to 1660 (Uknown 1725)**. The original engraving is held at the Rijksmuseum in Amsterdam.**

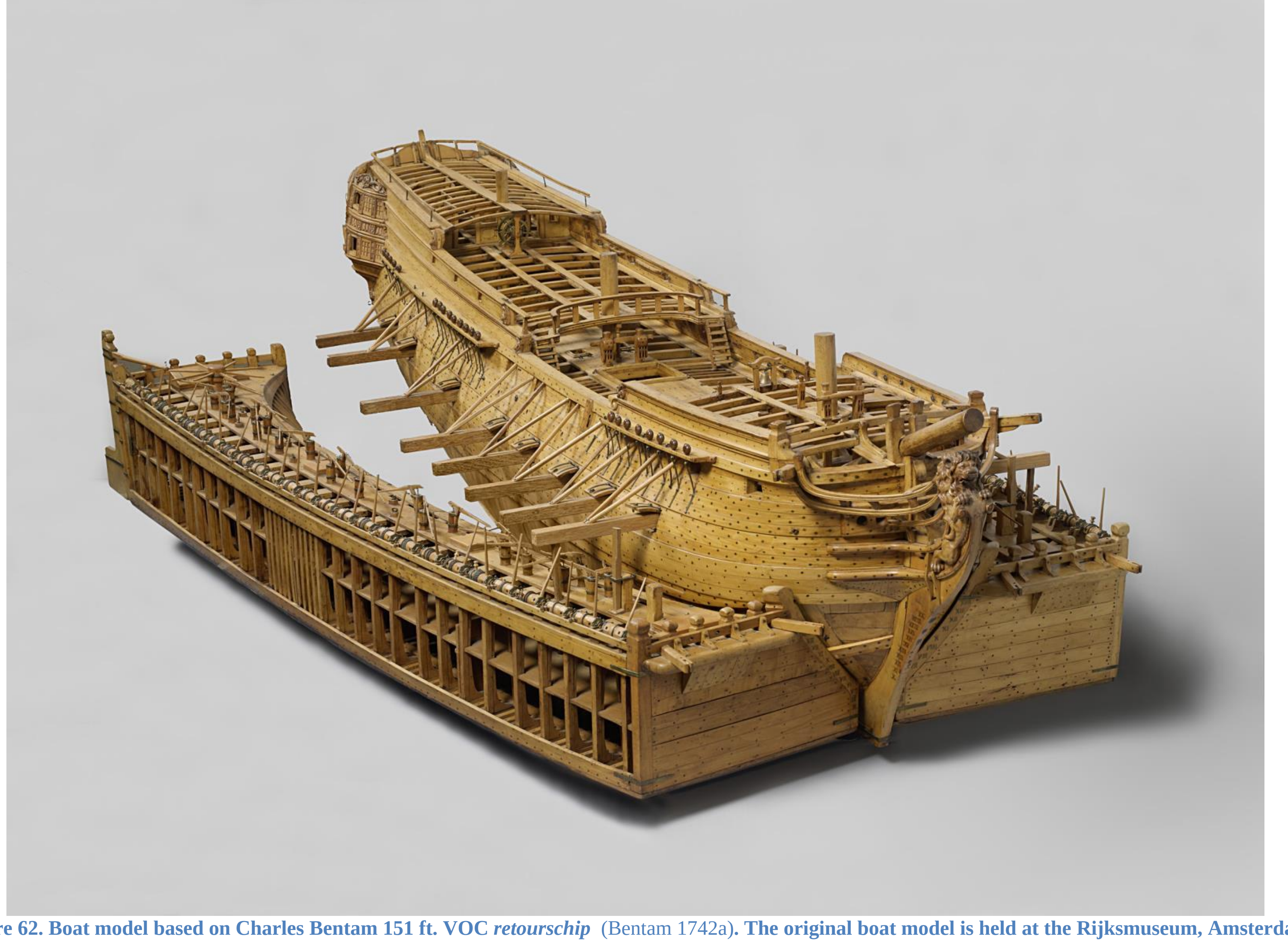

Figure 62. Boat model based on Charles Bentam 151 ft. VOC *retourschip* (Bentam 1742a)**. The original boat model is held at the Rijksmuseum, Amsterdam.**

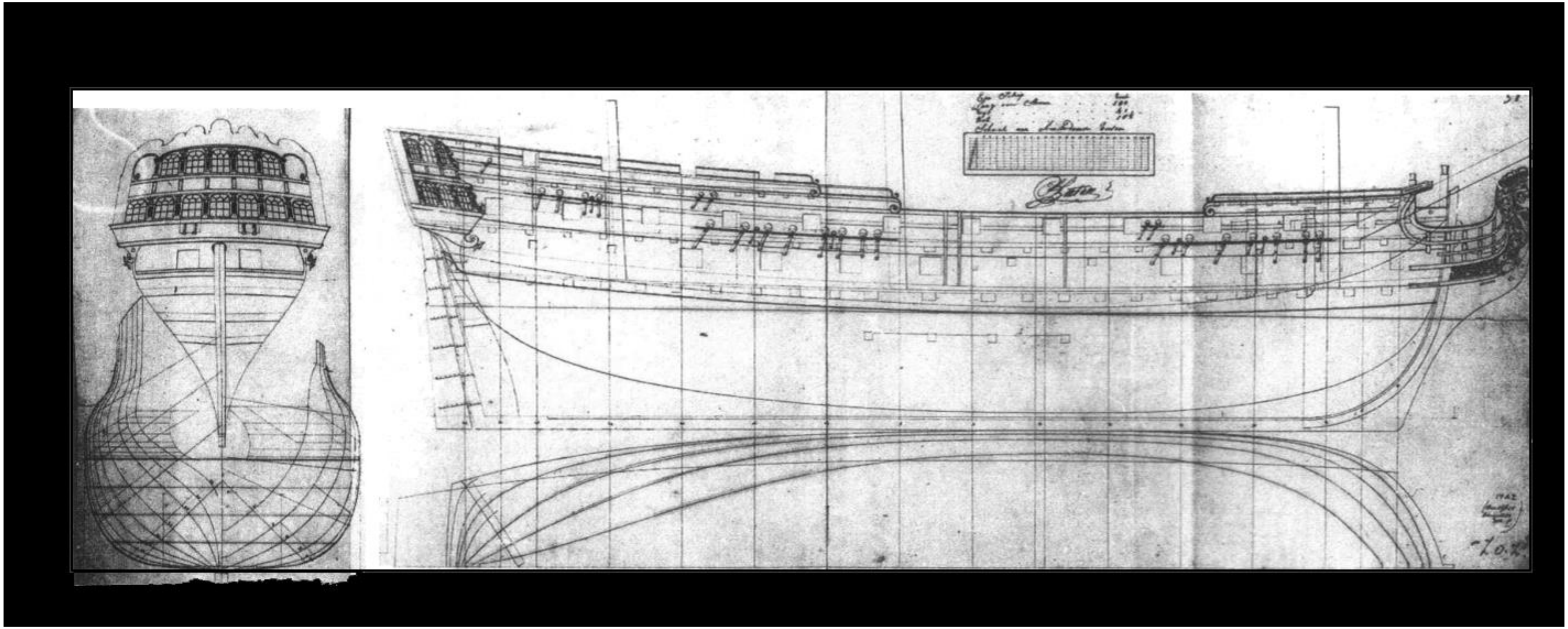

Figure 63. Ship plan with the Charles Bentam 151 ft. VOC *retourschip* from 1742 (Bentam 1742a, 1742b)**. The plans are held at the Rijksmuseum, Amsterdam. The author of this thesis processed the image to enhance the ship's lines.**

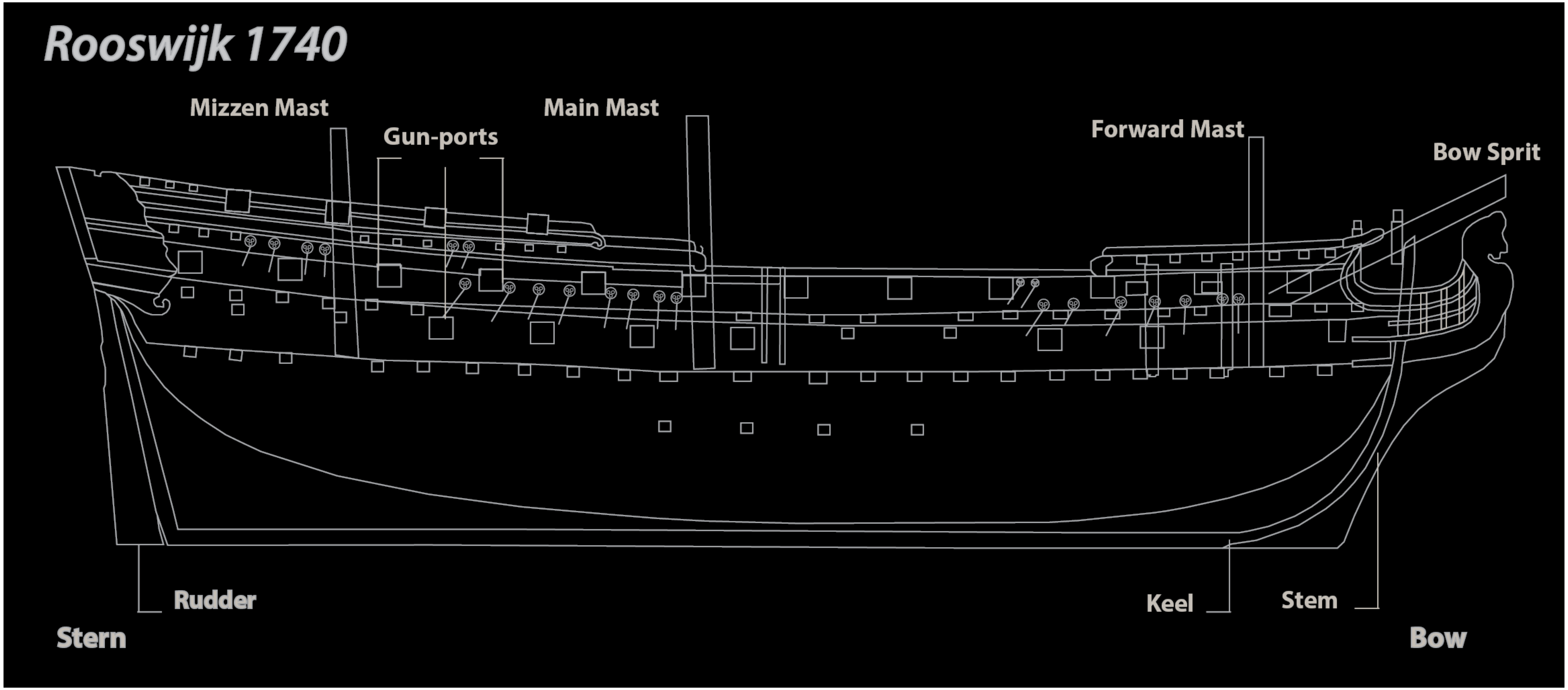

Figure 64. The image shows a hypothetical profile of the *Rooswijk 1740* is based on the Bentam plans from 1742 (Bentam 1742b)**. The author of this thesis created the image based on the previous figure.**

6.1.2 Service at the VOC

The *Rooswijk* had a very short service for the VOC, she only completed her maiden voyage successfully to Batavia and back under the command of Adriaan van Rensen. She parted on 24th October 1737, passing by the Cape of Good Hope (South Africa) on 8th June 1738, 227 days after departure, arriving in Batavia on 23rd September, 88 days after departure from the Cape and 334 days after departure from the Texel (Nijhoff 1979a:458; Open Archives 2018). The *Rooswijk* went back, under the command of Jacob Verleng to Amsterdam on 25th December 1738, arriving safely on 11th July 1739 (Nijhoff 1979b:348).

The *Rooswijk* attempted a second trip to Batavia, leaving from the Isle of Textil on 9th January 1740. On the way, she encountered a violent storm and was lost in the Goodwin Sands. The wrecking event was so sudden that it left no survivors to account of how it happened. Therefore, the *Rooswijk's* wrecking process interpretation depends entirely on the archaeological record.

6.2 Previous Work on Site

In December 2004 Ken Welling the current licensee[302], found the wreck in the Kellett Gut of the Goodwin Sands, off Kent. In 2005, a team led by Rex Cowan carried out a salvage expedition in close cooperation with the Dutch ministry of finance. The excavation of 2005 was crucial, as they located key features, artefacts and areas that allowed for the team in 2017 and 2018 to have a targeted excavation. From the work carried out in 2005 a number of the finds were recovered and sold in 2006 in Illinois, United States (Ponterio 2006; WA 2007:2), while other artefacts went to the Vlissingen Museum, in the Netherlands (Zeeuws maritiem muZEEum 2018).
In 2016, the Cultural Heritage Agency of the Netherlands, *Rijksdienst Voor Cultureel Erfgoed* (RCE), and Historic England (HE) created a joint project to survey and excavate the *Rooswijk*[303]. The Rooswijk Project brought together members from the 2005

[302] A Licensee is a voluntary custodian of the site. It is important to note that the role of Licensee for a Protected Wreck Site does not confer ownership or salvage rights. (HE 2015: 2).
[303] In 2016 the Rijksdienst Voor Cultureel Erfgoed (RCE), the Cultural Heritage Agency of the Netherlands, contracted MSDS Marine as the diving and survey contractor as well as the UK project managers.

expedition with an international team of commercial divers and archaeologists that carried out the excavation during 2017 and 2018. During 2017 and 2018 a group of NAS divers also surveyed the North (Barrel) Site and the East Site (Gun) (Beattie-Edwards 2018). The artefacts recovered during the excavation are currently going through assessment, analysis and conservation phases at Fort Cumberland, under the supervision of HE and MSDS Marine Ltd (MSDS Marine Ltd 2018).

6.3. Location and Hydrodynamics

The *Rooswijk* is located 8 miles (12.8 km) offshore from Kent, in the Goodwin Sands, southeast of the North Sands Head, northeast of the Kellet Gut, and northwest of the North Head of South Calliper (Figure 65). The site lies in 21m. of depth[304] with variations of 1 or 2 metres depending on local sediment migration, based on the seasonal tidal flow. The site lies in an extremely complex environment, the long-term evolution which is not fully understood (Cloet 1954; Cook 2016; Eldersfield 2001; UKHO 2015c, 2015b). The *Rooswijk is* located in a moderate-energy environment (M2aM[305]), with a few elements of disarticulated structure and many artefacts. The site conditions are dominated by strong tides, that are difficult to predict (velocity and direction), due to the changing morphology of the seabed.

(OSG36) Easting	(OSBG36) Northing	(UTM 31N) Easting	(UTM 31N) Northing
649515.948	158901.184	400676.30	5681323.24

(WGS84) Latitude	(WGS84) Longitude
51.274583	1.576067

[304] CD based on the 2018 MBES carried out by MSDS Marine Ltd. Kindly provided by PAS.

[305] See chapter IV section 4.3

The *Rooswijk* is located in the Kellet Gut, between the Goodwin Knoll and the Northern Head of South Calliper. The Goodwin Sands is divided into two main sections, the North Sand (Goodwin Knoll) and the South Sand (South Calliper). A channel runs between them known as the Kellet Gut[306] (Monkhouse 1970; PAS 2017; UKHO 2013b, 2015d) (Figure 65). The Goodwin Sands is mainly composed of current tidal sandbanks, which are relatively mobile, their extent and distribution being actively influenced by ongoing hydrodynamic processes and subsequently changing naturally over time (Dyer and Huntley 1999). The Northern Head of South Calliper has had a clear tendency towards eastward migration, from 2009 to 2015 (UKHO 2015d:3,7)(Figure 66 (B and C)), while the rest of the bank system appears to be rotating in a clockwise direction away from the north-south alignment. The Northern Head of South Calliper is 500 m away from the East Site of *Rooswijk*. The sandbank that has covered the East Site is one of the tails of the Northern Head of South Calliper (Figure 66).

The designated area covers a radius of 225[307]m that encompass four known areas that are part of the remains of the *Rooswijk*. These are three main sites: West site (The main site), East site and the North site (Figure 67). The main site consists of a wreck mound 27m long by 24m wide (Figure 67), the East site, a probable impact site, which is currently entirely covered by a sandbank (2018) and the North site is an area of 19 x 13 m, with concreted barrels and copper pots (Beattie-Edwards 2018). There is a debris trail between the East and the main site, which includes an anchor (PAS 2017). Lastly, there is a Northeast site (Gun site), that was clearly identified on the MBES from 2017. This area was less exposed during the 2016 survey as it is only possible to clearly make out one of the possible guns and a very slight impression of two others (PAS 2017:9–10)[308] (Figure 67).

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[306] A gut is a narrow channel opening into the sea or a large estuary.
[307] This changed from 150m radius to 225m on 23rd February 2018.
[308] This area lies outside of the 150m radius designated area of protected at 250 m. northeast of the West site (main site).

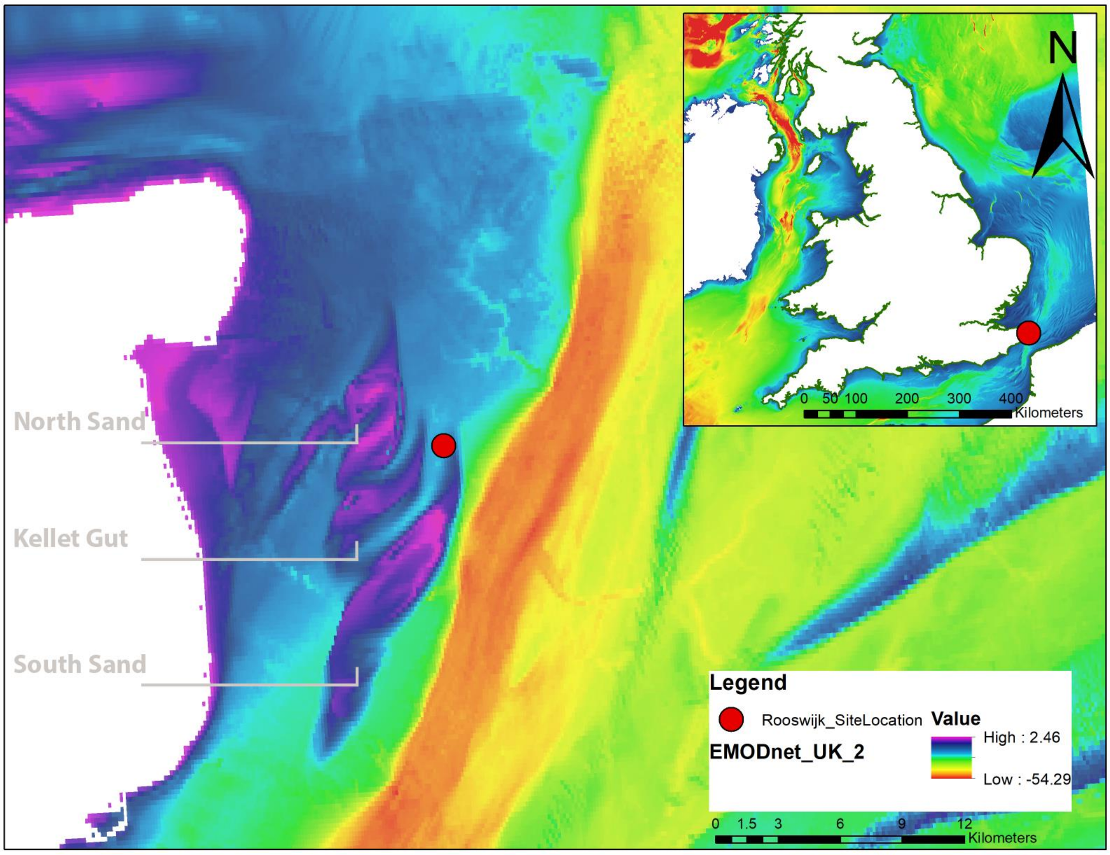

Figure 65. The map presented the Southeastern Coast of England, with the *Rooswijk* site location according to HE (2018b)**. The projected coastline is the World Vector Shoreline (WVS) from NGA** (National Geospatial-Intelligence Agency 2018)**. The bathymetry and UK territorial waters are sourced from EMODnet** (EMODnet 2018)**. Maps created by the author in ArcMap® 10.5.**

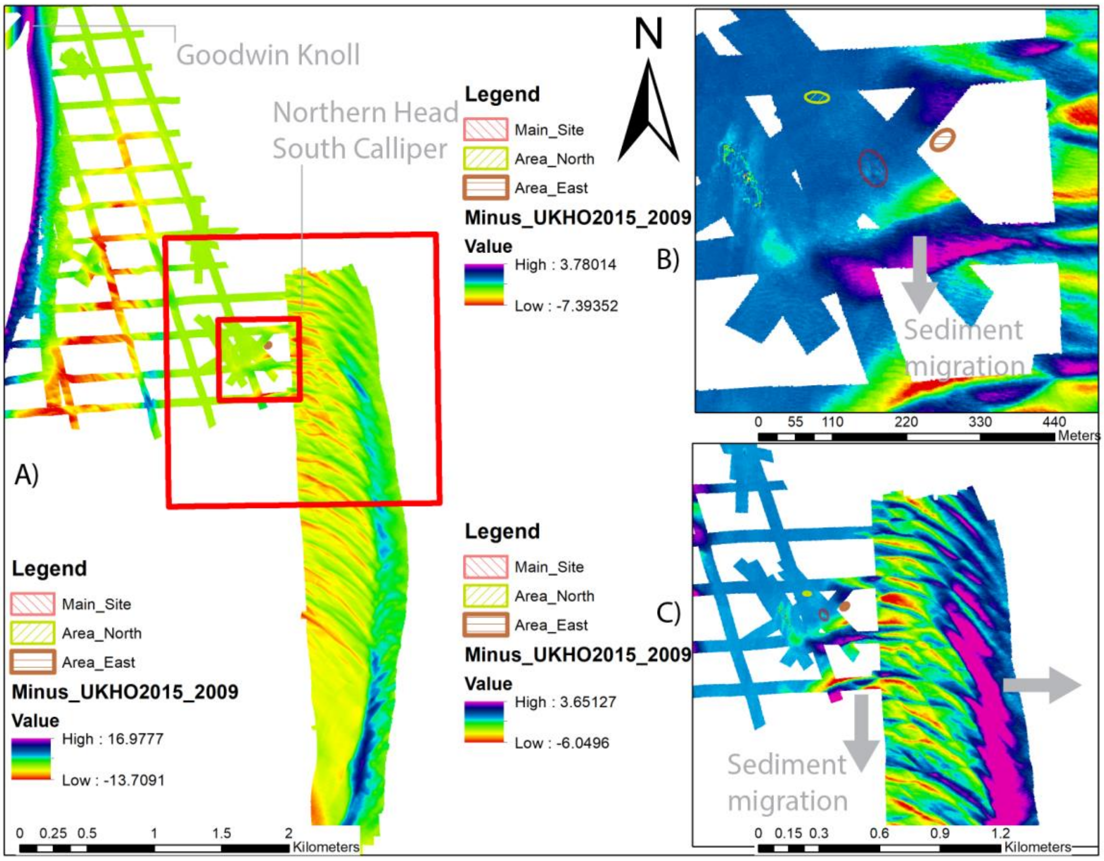

Figure 66. The figure shows a short time-lapse from 2009 to 2015 based on UKHO data (UKHO 2018b)**. A) An overall view of the Northern Head of South Calliper and Goodwin Knoll. B) Close up of the *Rooswijk* designated area, showing sediment migration direction. C) Close up of Northern Head of South Calliper, showing sediment migration direction. The author of this thesis created the map in ArcMap 10.5®.**

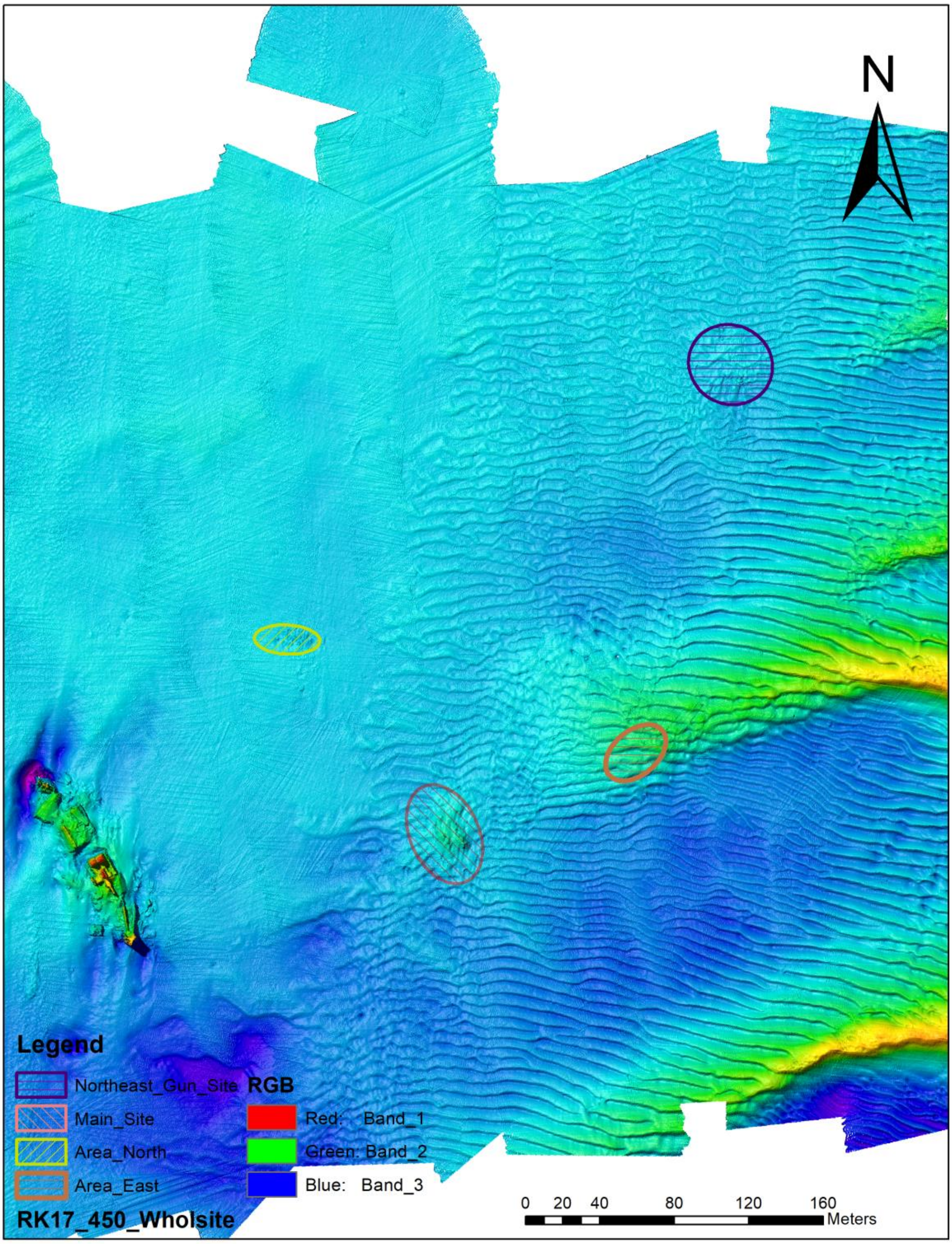

Figure 67. The figure shows four areas of the *Rooswijk* wreck site. The East site (Main site), West site, North site and Northeast Site. The data was kindly provided by PAS, commissioned by HE to manage the Goodwin Sands and Downs MB Survey (PAS 2017)**. A collaborative team including Pascoe Archaeology, MSDS Marine Ltd and Swathe Services carried out the survey. The author of this thesis created this map in ArcMap 10.5 ®.**

6.4. Seabed Geology and Sediment Transport

6.4.1 Geology

The Goodwin Sandbanks' full extent covers an area of approximately 220 km^2 with 22 km in length by 10 km in width. The Upper chalk bedrock averages at -20 m, also observed on the *Rooswijk,* going down to -40 m (Astley 2016; Carrizales 2010). On a low tide large areas of the top of the sandbank rise 1m above sea level. For example, the crest of these mobile sandbanks can be observed on low tide on the Protected Wreck *Admiral Gardner*, which is currently completely buried.

The Goodwin Sands consists of sandy sediments (sand, gravelly sand, sandy gravel, slightly gravelly sand, gravel (Long 2006)(Figure 68)), that overlie a chalk platform (BGS 2018b). The Kellet Gut has some of the finer sediments with sand and sandy gravel. During the excavations of 2017 and 2018, *in situ* observations report that below the fine sand layer, approximately 1-1.5 m (depending on the area and seasonal changes), the wreck lies on a solid muddy-chalk base.

The impact of dredging activities causing morphological changes to the Goodwin Sands is still unclear, potentially having a major impact on the underwater cultural heritage (*Rooswijk, Stirling Castle, Northumberland, Restoration, Gad 8, Admiral Gardner* and many more). From 1976 to 1998, over 9.5 million tonnes, with over 6.3 million m^3, of material have been extracted (Cook 2016:387). An additional 2.5 million m^3 are planned to be extracted from the western flank of South Goodwin Sands, located 5km (at its closest point) from the adjacent shoreline (Cook 2016:5, 9). Dredging this vast amount of sand has the potential of covering or uncovering complete wreck sites within the area. In addition, it could alter the tidal flow patterns and/or wave transformation processes of the seabed. These changes could potentially extend to either (Cook 2016:387):

- Altered tidal flow and/or wave patterns having a direct impact on the seabed of other areas of the Goodwin Sands, and the shoreline, thereby increasing coastal erosion or sea flooding risk.
- Altered sediment transport processes, which in turn could alter the seabed of other areas of the Goodwin Sands, shoreline erosion or deposition patterns.

The dredging activities represent a major risk factor for all wrecks in the Goodwin Sands, and the impact on historically significant wooden vessels is likely to be greater. The alteration of tidal flows, wave patterns and sediment transport dynamics could potentially uncover, scour and/or deteriorate the wrecks in the area. Furthermore, it also opens the possibility of uncovering or exposing wrecks that were unknown, and therefore, monitoring these changes should be undertaken considering the high archaeological potential.

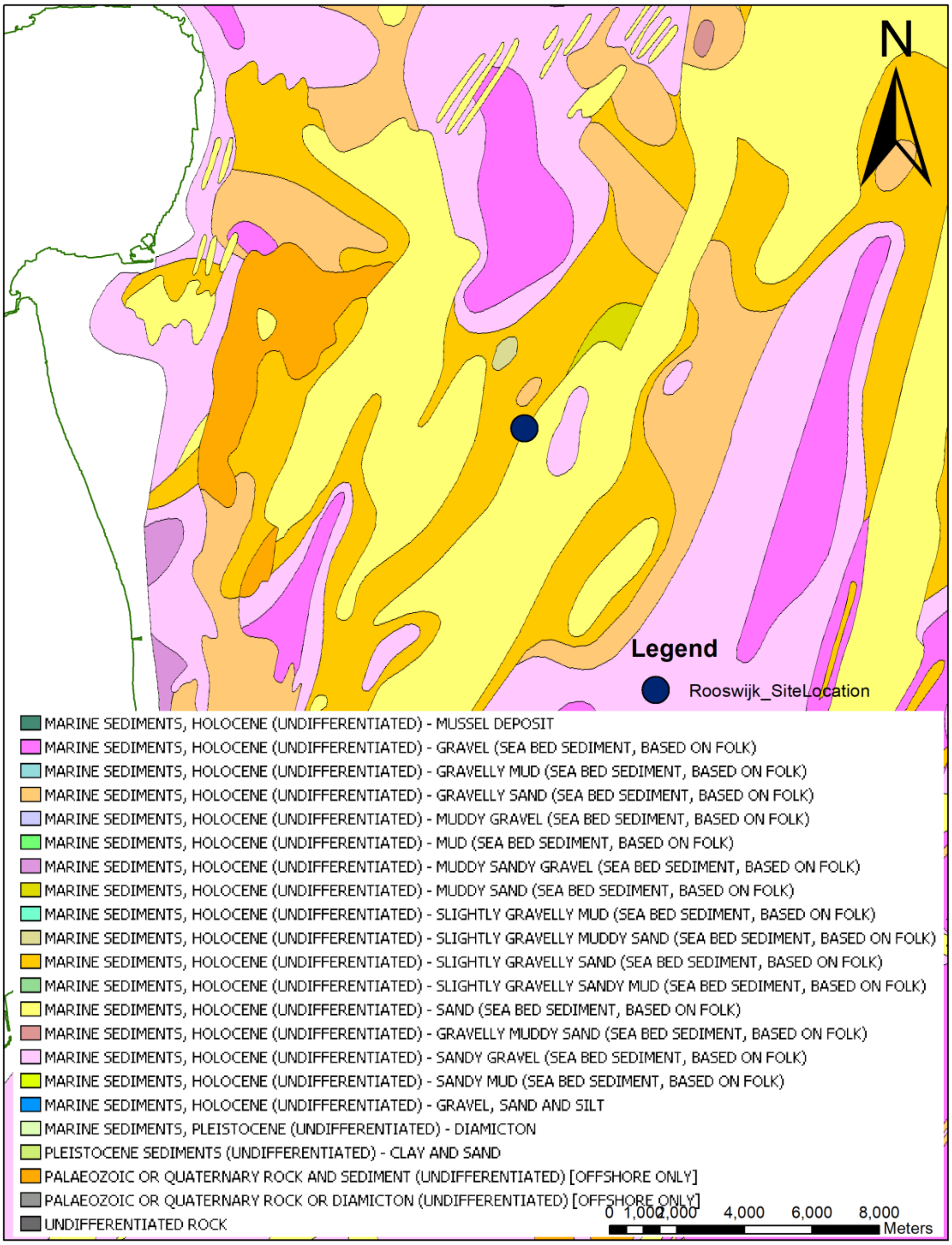

Figure 68. The map shows the seabed classification according to EMODnet (EMODnet 2018)**, based on modified Folk** (Long 2006)**. The site location is according to HE (2018). The author of this thesis created the map in ArcMap 10.5®.**

6.4.2. Sediment Transport

Sediment transport of the seabed is subject to wave action (winds, storms, and fetch) and/or tidal currents. Shallow water sites (< 10 m), have been observed to have a wave-dominated site formation process[309], with a direct impact on the wrecks' remaining structure. As observed by Quinn on *Invincible* (Quinn et al. 1998)*, Fouguex* (Fernández-Montblanc et al. 2016) and *Hazardous* (Grant 2016; HWTMA 2006). However, sediment transport in deeper sites (> 10 m), tend to be dominated by tidal flow. Astley (2016:173, 163, 259, 264) observed that on the *Stirling Castle* (-18 m), and *Burgzand Noord* site, the sediment transport was mainly tidally induced. More analysis is still needed to determine sediment transport regimes, however, this has been observed on the *Northumberland* (-14 m), and *Restoration* (-14 m), in the Goodwin Sands (PAS 2017).

The *Rooswijk* lies on the seabed in around 20 to 24 metres of water, depending on the tide, sediment migration and the area (main site or west site, north site, east site and northeast site). Because of the depth, the sediment transport is dominated by tidal action instead of storm action which would happen on shallower sites.
The macro-scale timelapse based on MBES survey from the UKHO suggest a migration pattern of Northern head South Calliper to the south and southeast (Figure 66). This migration pattern will eventually expand the Kellet Gut, in which the *Rooswijk* lies. However, further research still needs to be carried out to fully understand sediment migration on a macro-scale and the effects of prolonged swell and winter storms on the seabed.

6.4.3 Tides

On a macro-scale, tidal currents in the Goodwin Sands area are complex, the current flows rapidly westward immediately prior to low water and while the tide is flooding. The current begins to slow, during mid-flood and the direction changes to the north at high water, shifting towards the northeast as the tide begins to ebb. During the ebb tide, the current velocity increases as it flows northeast. The current velocity begins to slow during mid-ebb as the current direction changes to the west. This cycle suggests that the current direction continuously rotates clockwise, yet the Goodwin Sands have been rotating in an anticlockwise direction (Cloet 1954:204; Cook 2016:74; Kenyon

[309] See chapter V on *Hazardous* or chapter VII on *Invincinble*

and Cooper 2005; PAS 2017:6). Larn and Larn (1995) suggest that the North Sand Head may be the pivot for the rotation, based on aerial photography observations. Despite the general anti-clockwise movement of the large sandbanks of the Goodwin Sands, there is also localised movement of smaller sandbanks that follow different directions.

On a mesoscale, predicting or monitoring the tide is challenging. On an intra-site scale observation during the excavation of 2017 and 2018, the tidal predictions were extremely varied. The velocity of tidal currents varies considerably during springs or neaps around the UK, and the Goodwin Sands no the exception. During spring tides, the flood currents can reach maximum of 3 knots (1.6 m/s) [310] in a north-easterly direction and 2.7 knots (1.4 m/s) during the ebb, in a south-southwesterly direction. During neap tides, the maximum flood and ebb current velocities are reduced to just under 1.9 knots (1 m/s) (Astley 2016:168) (Figure 69).

During the excavations of 2017 and 2018, it was observed that the slack tides for both High-water (HW) and Low-water (LW), could be over 1 hour earlier than the tidal predictions charts from the Admiralty Total Tide (ATT) (UKHO 2018a). These variations depend on the seabed morphology that is in constant change, specifically, in this case, because of the mobile sandbanks that are immediate to the wreck that will determine both the direction and the velocity of the tide.

Specific site modelling of tides would require a permanent station on the seabed to measure the tidal velocity (ValePort 2018). The tides have a great impact on site, and they vary on a seasonal basis. However, this change on the seabed is difficult to measure. *In situ* diver's observations during the excavations 2017-2018, reported mobile sand dunes of 1-1.5 meters that moved around the wreck with the tides, covering or uncovering archaeological features. The only accurate method to map these intra-site dynamics would be with a short-interval high-resolution MBES survey, having a comparison during neap and spring tides.

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[310] 1 knot = .5144 metres per second

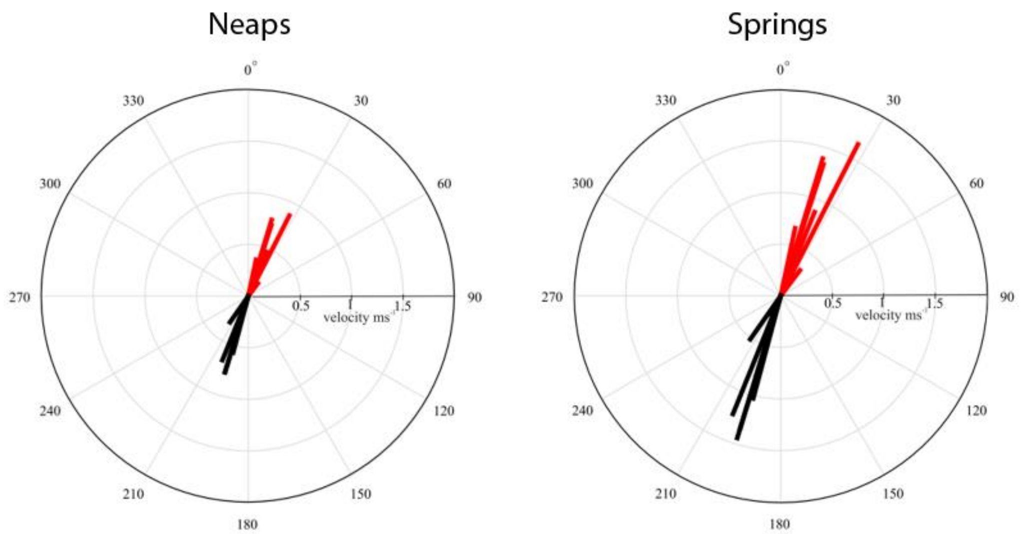

Figure 69. The figure shows direction and magnitude during spring and neap tides. The author of this thesis modified from Astley (Astley 2016:171) that was based on (Admiralty chart 1828, tidal diamond H).

6.4.4 Waves and Storminess

Waves approaching the Goodwin Sands are a combination of some long period swell waves, coming from the English Channel, and locally generated wind waves. The predominant wave direction is from the southwest for both swell and wind waves (Cook 2016:71; HR Wallingford 2015). The nearest wave buoy to the *Rooswijk* wrecks is the Goodwin Sands buoy, from CCO at approximately 7 km (4.35 miles) (Figure 70). The buoy measurements between 2008 and 2014 indicate that the dominant wave direction is from the South (Figure 71 (A))(Astley 2016:172). However, this wave buoy is sheltered from waves from the East (Cook 2016:71). HR Wallingford (2015a) modelled baseline conditions with data from 1986 to 2006 for the South Goodwin and South Calliper (Figure 71 (B)), showing approaches predominately from the southwest.

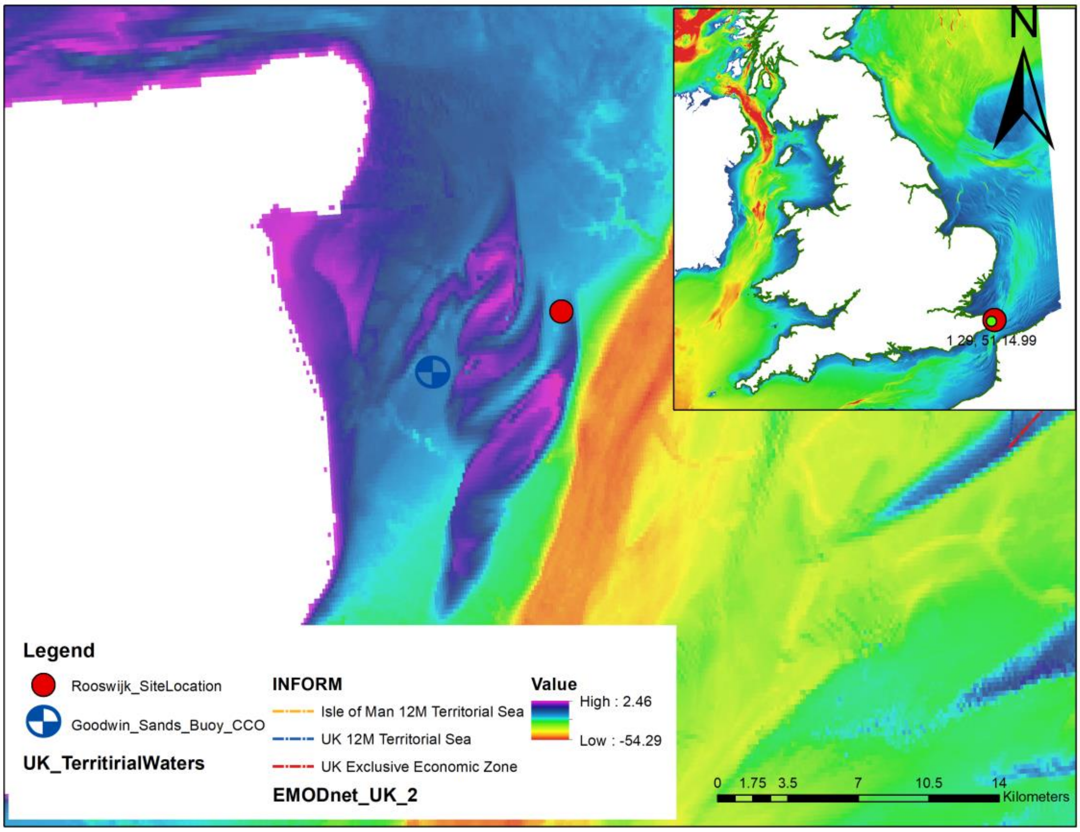

Figure 70. The figure shows the location of the Goodwin Sands buoy first deployed on 6 June 2008 according to CCO and the Rooswijk site location (HE 2018). The author of this thesis created the map in ArcMap 10.5®.

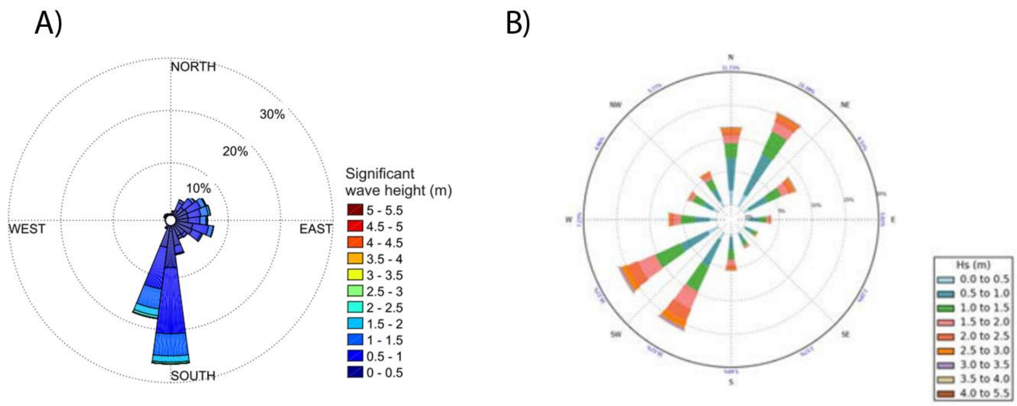

Figure 71. A) Wave directional rose for the Goodwin Sands, form wave rider buoy for the period of 2008- 2014. Data from CCO. The figure was taken and modified from (Astley 2016:172). **B) Significant wave heights predicted approaching from 30o, 90o, 120o and 240. Data from the UK Meteorological Office modelled by HR Wallingford. The author of this thesis created the figure.**

6.4.5 Energy

The energy levels around the Goodwin Sands will vary depending on winds, waves, fetch, seabed topography and depth. The EMODnet (EMODnet 2018) classification map located the *Rooswijk* in a moderate (M2aM[311]) shallow circalittoral environment, whereas the *Stirling Castle, Admiral Garner, Restoration* and *Northumberland* are in high energy, shallow circalittoral environments (Figure 72). The main difference between the *Rooswijk* and the *Stirling Castle, Admiral Garner*, *Restoration* and *Northumberland* is the depth of the site. According to the EMODnet environment classification, the *Rooswijk* has a lower energy level, because of the lower impact of storm activity to the seabed.

However, a closer examination of high-resolution data sets at a meso-scale and *in situ* observations at an intra-site level suggest that the *Rooswijk* is better classified as high-energy (H3bM[312]) environment.

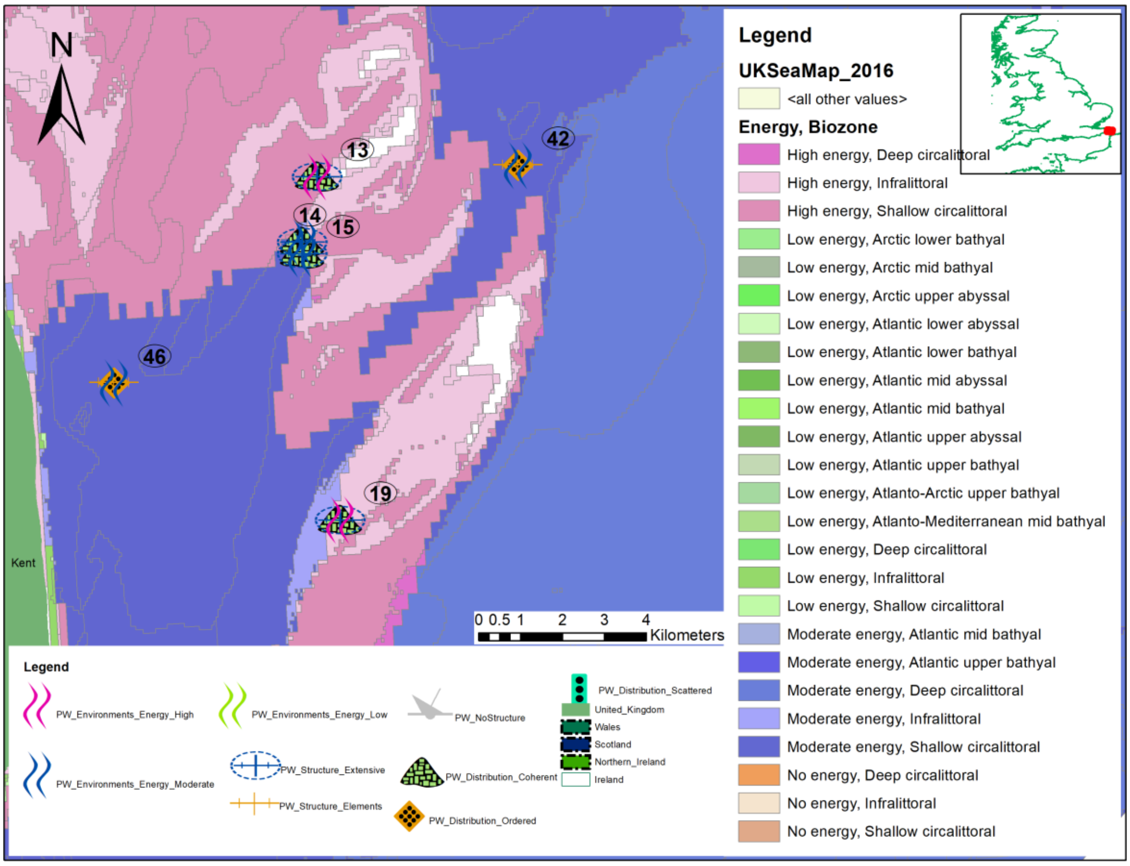

Figure 72. The map shows an Environmental classification according to Energy levels based on EMODnet (EMODnet 2018)**. The Protected wrecks shown on this map area: 13) *Stirling Castle*, 14) *Restoration*, 15**

311 Table 21.

312 Table 20.

***Northumberland*, 19) *Admiral Gardner*, 42) *Rooswijk* and 46) Gad 8. The author of this thesis created the map in ArcMap 10.5®.**

6.5 Materials and Methods

The complexity of the dynamic environment in which the wreck of the *Rooswijk* lies requires a multiple-level approach as argued throughout this thesis. On a macro-scale, mapping the whole extent of the Goodwin Sands represents a monumental challenge. The United Kingdom Hydrographic Office (UKHO) has extensive survey areas GS1[313], GS2[314], GS3[315] and GS4,[316] with 6-year intervals (UKHO 2013a, 2015c, 2015b, 2015a). The Goodwin Sands area has been surveyed numerous times since 1979, with the full area last being surveyed in 2009 and a focused survey conducted in 2012 (UKHO 2015c:1). The UKHO Civil Hydrography Programme (CHP) and the Maritime and Coastguard Agency (MCA) can only cover a limited extent. The resolution for the purpose of mapping sediment migration at its best is of 1m (UKHO 2018b), which is not enough to monitor a wreck at a site-specific scale. However, EMODnet energy and environmental classification offer an important proxy to understand the regional impact of the environment on shipwrecks (EMODnet 2016, 2018). The EMODnet environmental classification[317] reveals areas of high to moderate energy in the Goodwin Sands. This has to be taken with caution, due to the resolution of the data sets[318], and the environments' dynamism.

On a mesoscale, to understand the site-specific dynamics and the current state of the remains of the wreck on the seabed, a systemic MBES survey needs to be carried out on at least an annual basis. On an intra-site scale, an Ultra-short Based Line system (USBL) was used to record artefacts' positions during the excavations of 2017-18. During the excavation of 2017, a limited photogrammetric survey was carried out of the main site (57.81 m^2).

[313] South Sand Head
[314] Gull Stream & North Sand Head.
[315] Northern Head of South Calliper.
[316] South Calliper & Goodwin Knoll.
[317] Further explained in chapter IV, section 4.15.
[318] Specifically, the MBES surveys, as the 20cm resolution acquired by MSDS Marine Ltd (from 2015 to 2018). That demonstrate a much higher resolution of sediment migration.

A comprehensive panorama of the wreck of the *Rooswijk* and its surrounding environment was only possible by integrating remote sensing datasets (macro, meso and intra-site scale) on a temporal-GIS platform. The reverse engineering of the wreck formation process has been challenging, but the extensive data sets, and *in situ* observation provided solid evidence of spatial distribution of artefacts. The study found artefacts within the 150m radius of the designated area as a Protected Wreck by HE. However, some artefacts might have been dragged outside of this perimeter due to tidal action over the past 250 years.

6.6 Results

The two main methods used to record the full extent of the *Rooswijk* site(s) and the distribution of artefacts across the seabed were site-tailored acoustic mapping (MBES) and positioning (USBL) systems. These remote sensing techniques were the ideal methods to survey the *Rooswijk*, in a challenging underwater environment.

6.6.1 Multi-beam Eco Sound (MBES) Time-series

This thesis is concerned with producing better archaeological results with integrated methodologies that aim to have better strategies for cultural heritage care. The systematic MBES time-series presented in this thesis allows comparable data-sets to be used to understand environmental dynamics as well as their impact on the UCH at a meso and intra-site scale.

The data sets from the surveys included in this thesis were conducted from 2015 to 2018 on an annual basis, by collaborative teams including Trenarch, RCE, Pascoe Archaeology, MSDS Marine and Swathe Services, commissioned and funded by Historic England (PAS 2017)[319] as follows:

[319] The *Rooswijk* surveys were done as part of a lager project that included over six designated sites and one un-designated site in the Goodwin Sands (*Northumberland, Stirling Castle*, *Restoration*, *Rooswijk*, and *Admiral Gardner*) on and The Downs (*GAD 8*) region. The '*Bowsprit Wreck*', was the un-designated site in the Goodwin Sands (PAS 2017:1).

- **2015**. Data owner is RCE, project manages by Trendarch, data collected by Swathe Services and processed by Swathe Services/MSDS Marine.
- **2016**. Data owner RCE, project managed by MSDS Marine, data collected and processed by Swathe Services/MSDS Marine.
- **2017**. Data owner HE, project managed by PAS, data collected and processed by Swathe Services/MSDS Marine.
- **2018** (pre-excavation). Data owner HE, project managed by PAS, data collected and processed by Swathe Services/MSDS Marine.

The MBES collected from 2015 to 2018[320], were carried out under the same high-standard parameters, specifically site-tailored to obtain the best resolution possible (Table 27). The R2Sonic 2024 MBES system allowed mapping the seabed from a waterborne vessel, covering both large extensions at 400 kHz and targeted areas at 700 kHz at Ultra High resolution (UHR), with a resolution of 0.20 m (PAS 2017:6) [321].

Rooswijk. **MSDS Marine Ltd**							
Date	**IMU Unit**	**Equipment**	**Frequency/ Resolution**	**Software Process**	**Format / RAW**	**Gridded Resolution/ Positioning**	**Datum**
2018	Applanix POS MV Wave Master	R2 Sonic 2024	450 and 700 khz	HyPack	.xyz	RTK / .20cm	WGS84/OD Dover
2017	Applanix POS MV Wave Master	R2 Sonic 2024	450 and 700 khz	HyPack	.xyz	RTK / .20cm	WGS84/OD Dover
2016	Applanix POS MV Wave Master	R2 Sonic 2024	400 and 700 khz	QINsy	.xyz	RTK / .20cm	WGS84/OD Dover
2015	Applanix POS MV Wave Master	R2 Sonic 2024	400 and 700 khz	QINsy	.xyz	RTK / .20cm	WGS84/OD Dover

Table 27. The table presents all the survey parameters used by MSDS Marine Ltd for the MBES surveys on the *Rooswijk* from 2015 to 2018.

[320] These MBES datasets identified changes over the sites of the several sites across the Goodwin Sands: *Rooswijk*, *Stirling Castle*, *Northumberland* and *GAD 23* (PAS 2017:1).

[321] At 450 kHz the 2024 has a beam width of 0.9° x 0.45° reducing to 0.6° x 0.3° when in 700 kHz UHR mode (PAS 2017:6). Further detail on MBES systems can be found in Chapter III, section 3.3.1.1.

6.6.1.1. Mesoscale

The macro-scale description of the Goodwin Sands established that the wreck site of *Rooswijk* is located in a dynamic environment that is dominated by tidal currents (Figure 68). However, it is important to understand the limitation of EMODnet data in terms of resolution for the areas that are less frequently surveyed[322]. The use of high-resolution data sets that cover the area of interest of *Rooswijk,* and the surrounding environment (Table 27), allowed modelling the seabed's dynamic nature. The mesoscale description of the *Rooswijk* site was achieved with a 450 kHz frequency that allowed having extensive coverage with a 30 cm resolution (PAS 2017). This was ideal to cover all the wreckage areas (west, east, north and northeast sites) and understand sediment migration patterns. On a local mesoscale, this dynamism becomes more evident with recurrent surveys over the same area and analysing the seabed forms. All seabed forms will be identified as subaqueous dunes[323], classifying them by shape and size (large, medium and small), morphology, seabed form behaviour and flow characteristics (Ashley 1990:166–69).

The west site (main site) of the *Rooswijk* includes numerous exposed features, anchors, guns, disarticulated structure and cargo. Previous work on site, based on the recovered artefacts, suggests that that the remains of the bow are towards the southeast and the stern of the vessel towards the northwest (PAS 2017:7) (Figure 73 and Figure 77).

From the 2016 surveys, it was possible to identify that the East site was a scatter of small rectangular anomalies, probably granite blocks. There are several granite blocks on the main site (west site), that was part of the cargo. Additionally, concretions consisting of strips of iron and a single anchor were visible at the southern limit of the East site (PAS 2017:7) (Figure 73 and Figure 78).

The north site consists of a scatter of small anomalies, many of which have been identified as concreted barrels during a survey carried out by NAS during 2017

[322] See section 6.4.5 of this chapter for energy on *Rooswijk*. For further detail on environmental modelling see chapter IV, section 4.1 and section 4.3 explanations on the classification system based on the environments' energy.
[323] Subaqueous dunes is a term used to distinguish them from aeolian dunes (shaped by the wind).

(Beattie-Edwards 2018). There is a debris trail leading from the main site towards the north site (PAS 2017).
The northeast site consists of 10 guns that possibly belong to the *Rooswijk*. They were initially detected in the MBES survey of 2016 and clearly identified in 2017 (PAS 2017). In 2017 the NAS carried out diving operations to confirm the nature of this site and to record and tag these guns (Beattie-Edwards 2018).

In this section, only the three locations (west, east and north sites) within the designated protected wreck site of 150 m radius are described in the time-series. The northeastern Site (Gun Site) did not have complete coverage of previous surveys (2015 and 2016), as it was only in 2017 that these guns were identified on the MBES[324].

During 2015, a large sand wave with a compound form including a series of smaller dunes with 5-6 m spacing is visible to the north of the east Site (Figure 74 and Figure 75 (A)). The maximum height of that large dune is 2 m, with a well-defined ridge on the southern end of the large dune (Figure 74 and Figure 75 (A)). A series of sand "ripples" or small subaqueous dunes, with 5-6m spacing and 1-1.5 m in height run in an East-West direction (Figure 74 and Figure 75 (A)). These bedforms seem to be formed by the prevailing tide movement on site.

[324] The radius of the designated area should be considered to be expanded and include this Gus-site, as a possible first impact site.

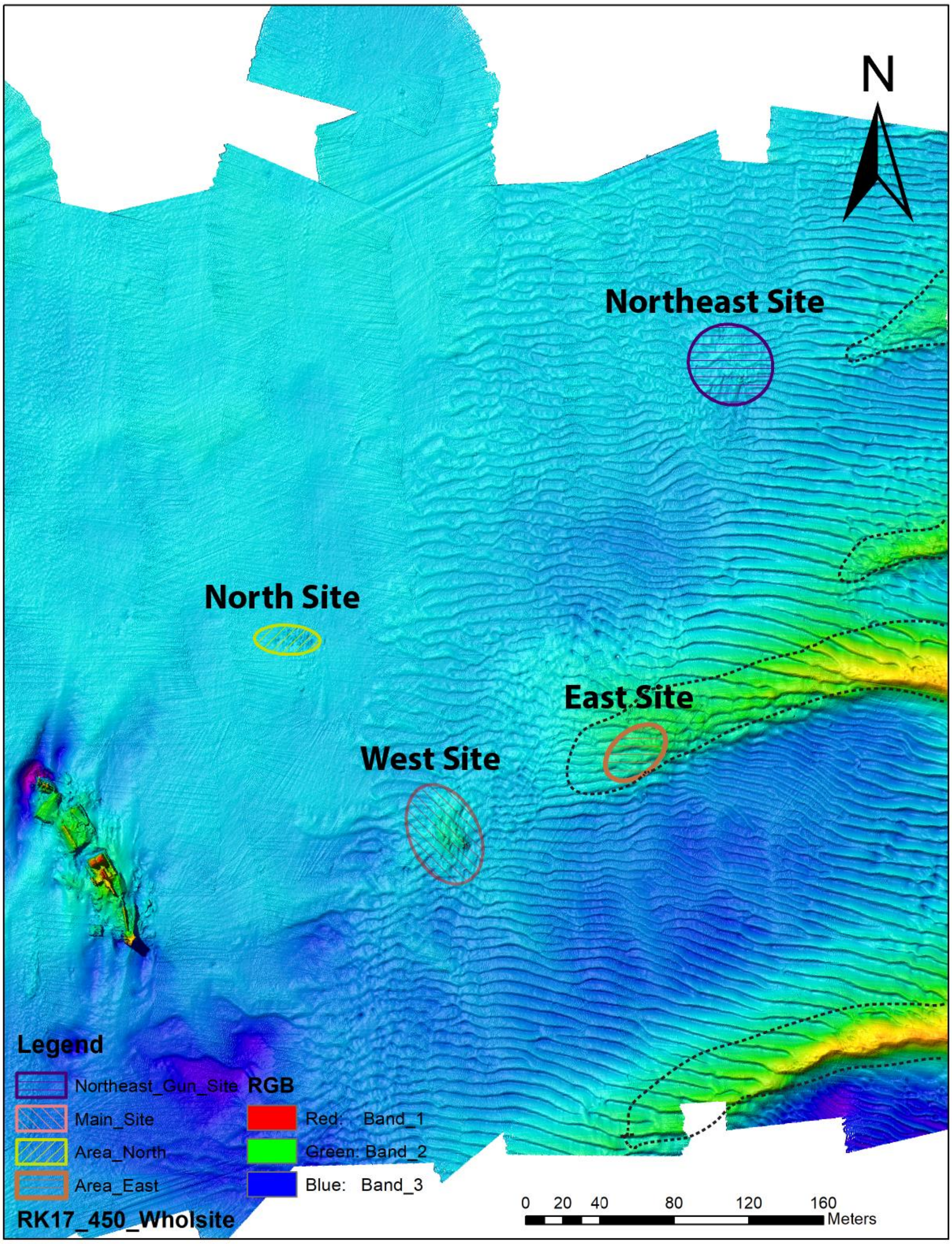

Figure 73. The figure shows the main site (West site), East site, Northeast site, and North site overlaid on 2017 MBES. The map delineates a series of tails or minor sandbanks from the Northern Head of South Calliper. The data was kindly provided by PAS, commissioned by HE to manage the Goodwin Sands and Downs MB Survey (PAS 2017)**. A collaborative team including Pascoe Archaeology, MSDS Marine Ltd and Swathe Services carried out the survey. The author of this thesis created the map in ARCMap 10.5®.**

In 2016, the large dune migrated 20 m south partially covering the east site (Figure 74 and Figure 75 (B), and Figure 76 (A)), whilst the ripples across the rest of the main site maintain a similar interval of 5-6 m. However, some of the small dunes become less defined to the west on the main site (west site) and to the south of the north site (Figure 74 and Figure 75 (B). These small dunes seem to have a trend to shift to the south at a slower rate than the large dune (Figure 76 (A)).

In 2017, the large dune continued its migrating trend toward the south, shifting another 20 m, with intervals of smaller dunes that are 6-8 m in height (Figure 74 and Figure 75 (C), and Figure 76 (B)). This large dune has completely covered the east site with 2 m of sediment and it has moved closer to the west site (main site), only 50 m away, when it was at a distance of 90 m in 2015 (Figure 74 (C)). To the west of the main site and to the south of the north site, the small dunes have disappeared, giving way to a flatbed (Figure 74 and Figure 75 (C)). This could be caused by the large dune shifting south and changing the tidal pattern around the site.

In 2018, the large dune had continued moving to the south another 25 m (Figure 76 (C)). The north site is still completely covered with over 2 m of sand (Figure 74 and Figure 75 (D)). However, if this trend continues the north site will be uncovered again by 2019, as observed in the changes between 2015 and 2018 (Figure 76 (D)). The large dune is running in an almost east-west direction only 40 m away from the main site. The small dunes with 5-6 meters of interval continue, well defined to the north and south of the large dune (Figure 74 and Figure 75 (D). These small dunes run across the west site (main site), in an east-west direction, with 1-1.5 m of height. To the west of the main site and towards the North site, the seabed continues to be a flatbed (Figure 74 and Figure 75 (D)).

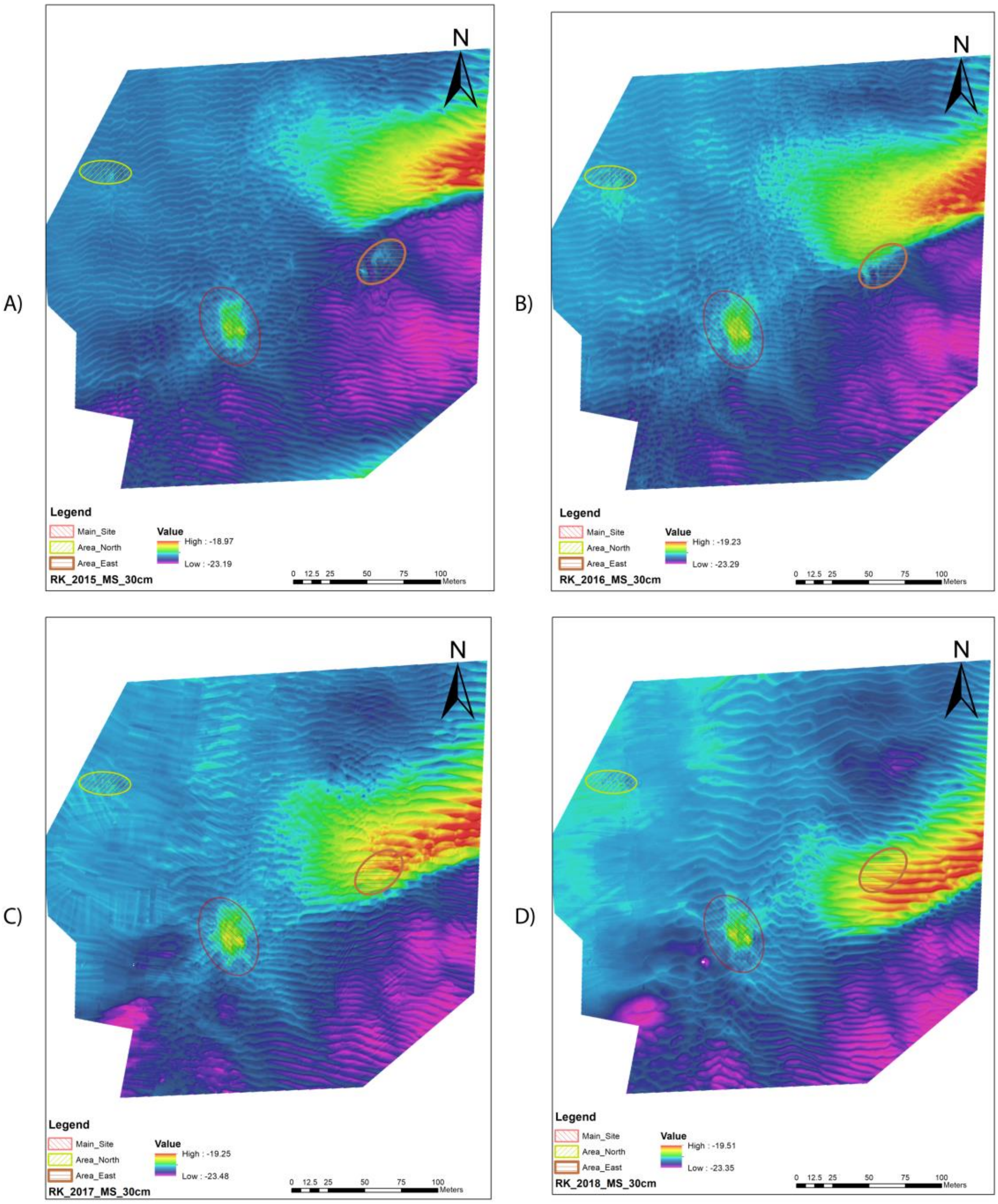

Figure 74. The figure shows a series of MBES surveys of the *Rooswijk*, highlighting the sites (East, West, North and Northeastern). A) 2015, B) 2016, C) 2017 and D) 2018. The data was kindly provided by PAS, commissioned by HE to manage the Goodwin Sands and Downs MB Survey (PAS 2017)**. A collaborative team including Pascoe Archaeology, MSDS Marine Ltd and Swathe Services carried out the survey. The author of this thesis created the maps in ArcMap 10.5®.**

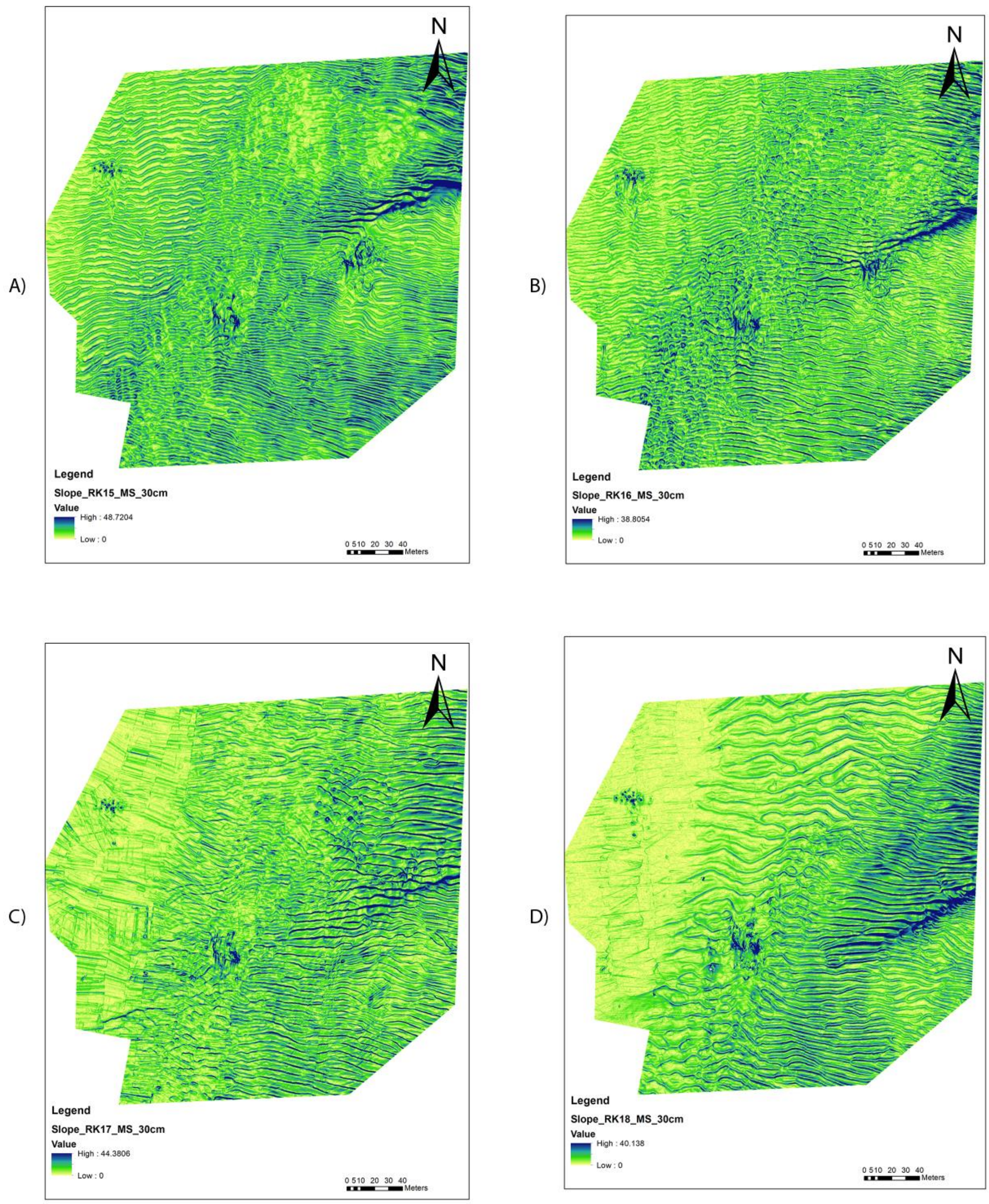

Figure 75. The figure shows a series of Slope analysis of the MBES surveys of the *Rooswijk*. A) 2015, B) 2016, C) 2017 and D) 2018. The data was kindly provided by PAS, commissioned by HE to manage the Goodwin Sands and Downs MB Survey (PAS 2017)**. A collaborative team including Pascoe Archaeology, MSDS Marine Ltd and Swathe Services carried out the survey. The author of this thesis created the maps in ArcMap 10.5®.**

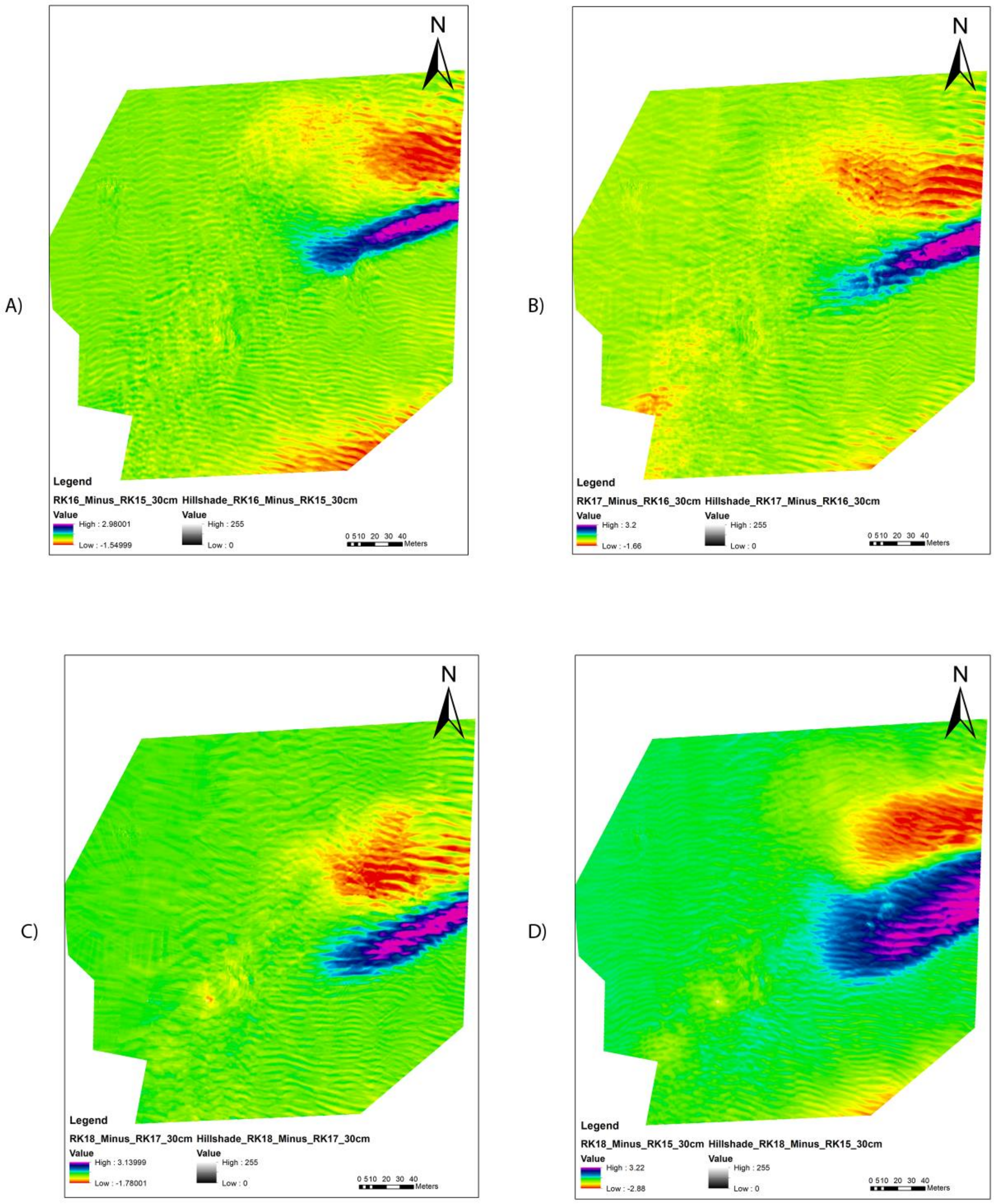

Figure 76. MBES time-series displayed in ArcMap 10.5®, showing sediment migration. A) 2015-2016, B) 2016-2017, C) 2017-2018 and D) 2015-2018. The survey was carried out at 450 kHz with an R2 Sonic 2024 system with a 30cm resolution. The data was kindly provided by PAS, commissioned by HE to manage the Goodwin Sands and Downs MB Survey (PAS 2017)**. A collaborative team including Pascoe Archaeology, MSDS Marine Ltd and Swathe Services carried out the survey. The author of this thesis created the maps in ArcMap 10.5®.**

6.6.1.2. Intra-site scale

The intra-site description of the *Rooswijk* site required higher-resolution data sets than the previously collected data. The R2 Sonic 2024 MBES system allows operating at 700 kHz for Ultra High Resolution (UHR). The R2 Sonic 2024 MBES allows the user to select the swath sector from 10° to 160°. However, when the UHR 700 kHz is selected, the swath sector will automatically be reduced to 70° (R2 Sonic 2016:63). By using a 700 kHz frequency instead of 450 kHz, the resolution can be increased to 0.1 m, but the coverage is reduced. The UHR surveys presented in this section targeted the west, east, and north sites.

The MBES can be processed and displayed with Cloud Compare®, or Fledermaus ® and later put onto a GIS platform ArcMap® or Q-GIS®[325]. There are advantages of displaying data with the Quinsy® and Fledermaus® suits. Visually, it creates an adequate colour scheme with a hillshade effect with shadows that enhance the image to distinguish artefacts on the seabed. However, this creates an RGB raster image[326] and not a single band raster[327] file with the added depth values (ESRI 2018b). This limits its capacity of using the spatial analysist tool on ArcMap®. It was therefore decided to create a single band raster file in Cloud Compare® and import into ArcMap® for further analysis. The colour scheme used to display the datasets matched the one used in Feledermaus® as close as possible, producing good results to identify archaeological features (Figure 77) (The images processed with Fledermaus® can be found in Appendix II. Rooswijk).

The seabed's dynamism becomes even more evident on a local intra-site scale than on a meso or macro-scale comparison.

The UHR surveys carried out on an annual basis allowed an understanding of localised phenomena, sediment migration and the erosion that artefacts endure in this

[325] Further explained in Chapter III (section 3.3.1.1).
[326] The RGB Composite renderer that allows you to combine bands as red, green, blue composites. When viewing colour photography or an orthophoto created with photogrammetry, you are viewing a three-band raster dataset.
[327] The stretched renderer displays continuous raster cell values across a gradual ramp of colours. The stretched renderer is used to draw a single band of continuous data, with a large range of values, such as elevation models.

environment. The analysis of sediment migration offers a new scope for understanding how this affects smaller artefacts that are not possible to map with MBES yet[328].

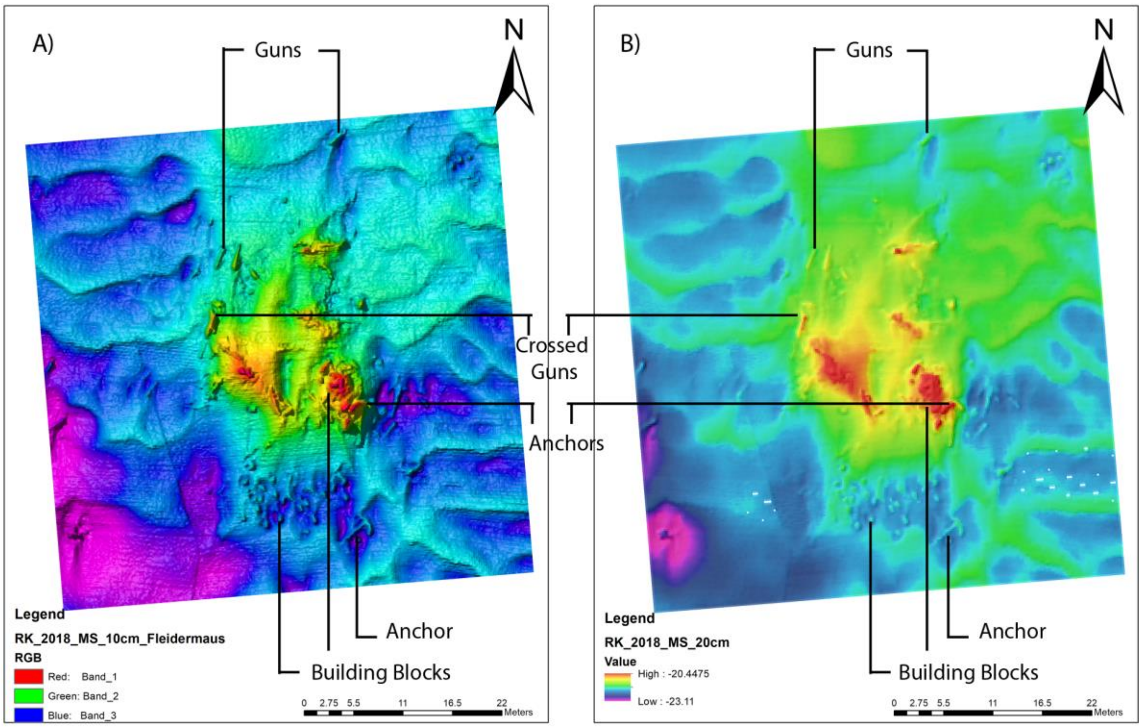

Figure 77. The figure shows a comparison of MBES surveys display of the West site in 2018. A) The survey displayed with Fleidermaus®. B) The survey processed with Cloud Compare® and displayed in ArcMap 10.5®. The data was kindly provided by PAS, commissioned by HE to manage the Goodwin Sands and Downs MB Survey (PAS 2017)**. A collaborative team including Pascoe Archaeology, MSDS Marine Ltd and Swathe Services carried out the survey. The author of this thesis created the maps in ArcMap 10.5®.**

At the main site (west site), the contour lines range from - 20.41 m (2015) at the shallowest, and - 23.1 m (2018) at the deepest, with a range of 2.69 m difference (Figure 78). The - 21.6 m (in orange) and - 21.8 m (in yellow) contour lines, delimits a perimeter around the site (Figure 78 (A to D)). Observing these contours lines provides an understanding of areas of erosion and accretion of sediment as well as scouring around the main site.

In 2015, the - 21.8 m contour delineates a mound that is surrounded by small dunes with an interval of 2-2.5 m. The mound has three protrusions in the centre that are two stacked anchors and granite building blocks at – 21 m to - 20.8 m (Figure 78 (A)). This represents 1 m of sand overburden difference between the surroundings and the central area.

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[328] See section 6.6.3.

In 2016, the - 21.8 m mound is reduced in size creating a more defined mound, but small dunes surrounding the site seem less defined) (Figure 78 (B). The mound presents erosion of 0.4 to 0.7 m that exposes more features in the central area of the mound (Figure 79 (A)).

In 2017, the 21.8 m conteour line was reduced even further and many of the features became even more defined in the central part of the mound (Figure 78 (C). This is due to more erosion of the mound, with sediment loss of 0.2 to 5 m metres (Figure 79 (B).

In 2018, the morphology of the mound changes, there is an evident accumulation of sediment on the northern section, visible in contour - 21.8 m, with 0.5 to 0.2 m of sand (Figure 79 (C). However, to the south, there is erosion that exposes another anchor and several granite blocks (Figure 78 (D), caused by 0.4 to 0.2 m of sand migration (Figure 79 (C). Overall, from 2015 to 2018 the central part of the mound and southern section have become more exposed, with evident erosion, while the northern section has gained sand 0.5 - 0.2m (Figure 79 (D). The change in morphology is probably determined by the large sand dune to the northeast of the main site shown in the mesoscale analysis (Figure 74, Figure 75 and Figure 76), that alters tidal movement that generates sand displacement.

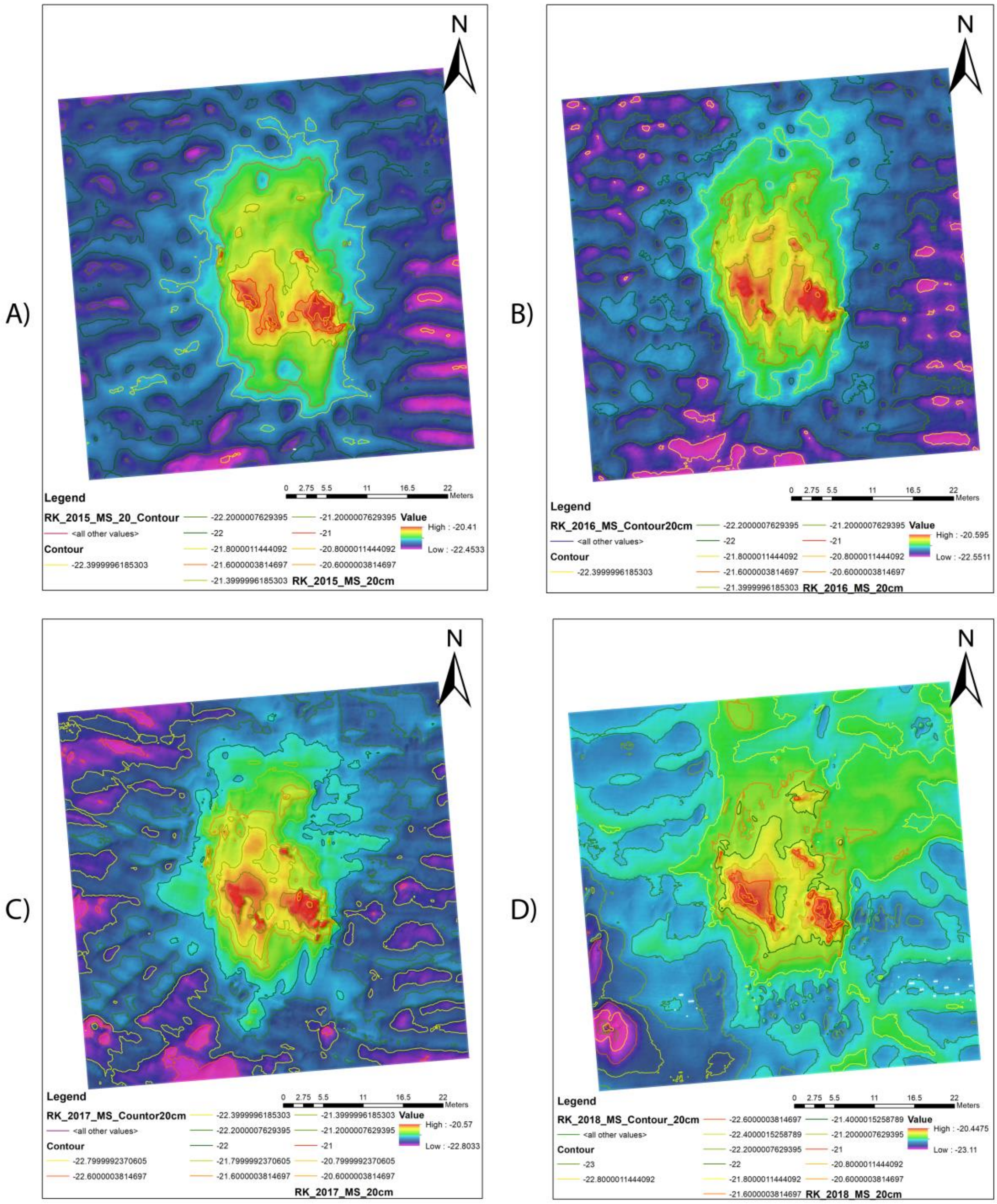

Figure 78. The figure shows a series of MBES surveys of East Site with a 20 cm contour. A) 2015, B) 2016, C) 2017 and D) 2018. The data was kindly provided by PAS, commissioned by HE to manage the Goodwin Sands and Downs MB Survey (PAS 2017)**. A collaborative team including Pascoe Archaeology, MSDS Marine Ltd and Swathe Services carried out the survey. The author of this thesis created the maps in ArcMap 10.5®.**

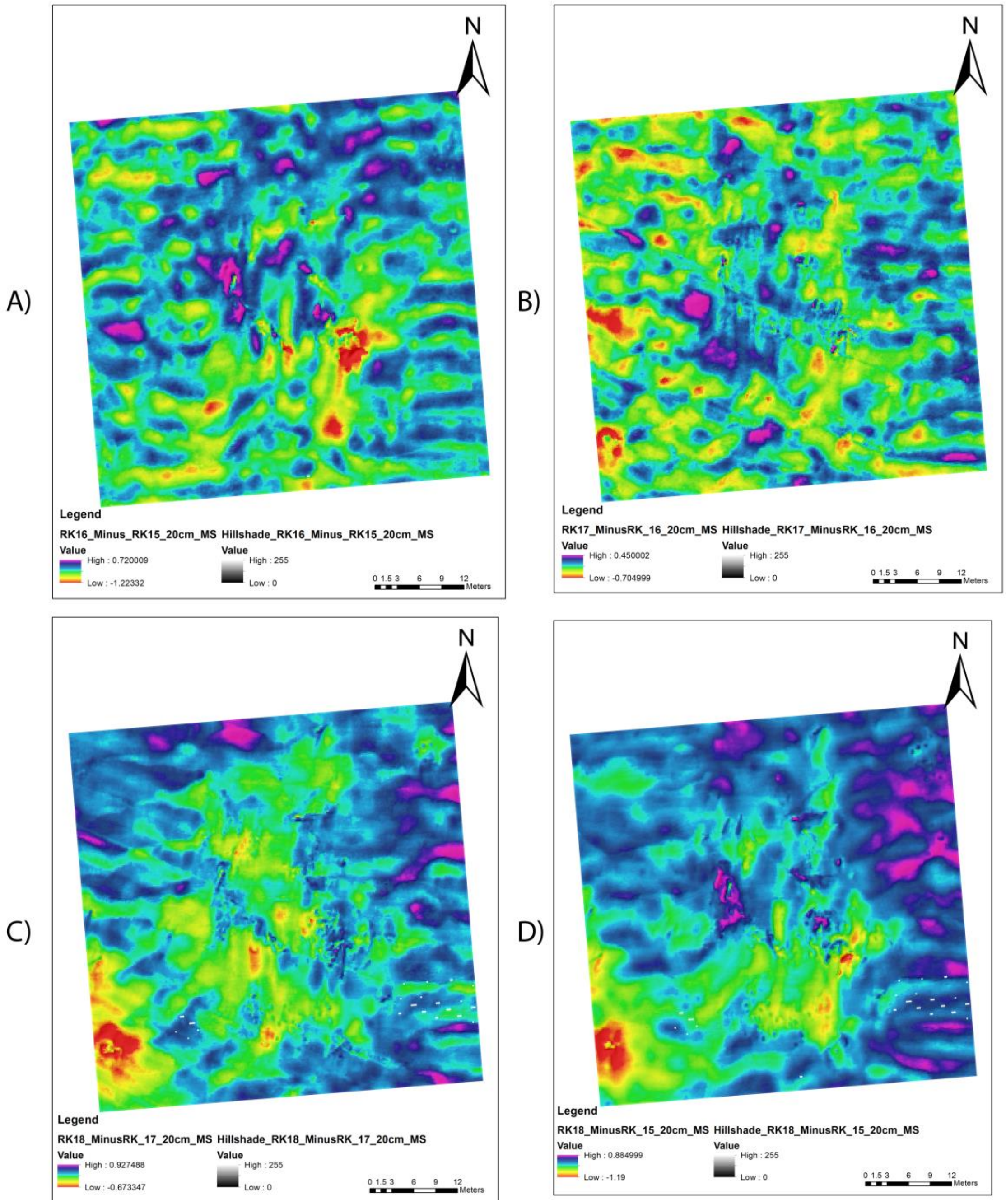

Figure 79. MBES time-series displayed on ArcMap 10.5®, showing sediment migration. A) 2015-2016, B) 2016-2017, C) 2017-2018 and D) 2015-2018. The survey was carried out at 700 kHz with an R2 Sonic 2024 system with a 10 cm resolution. The data was kindly provided by PAS, commissioned by HE to manage the Goodwin Sands and Downs MB Survey (PAS 2017)**. A collaborative team including Pascoe Archaeology, MSDS Marine Ltd and Swathe Services carried out the survey. The author of this thesis created the maps in ArcMap 10.5®.**

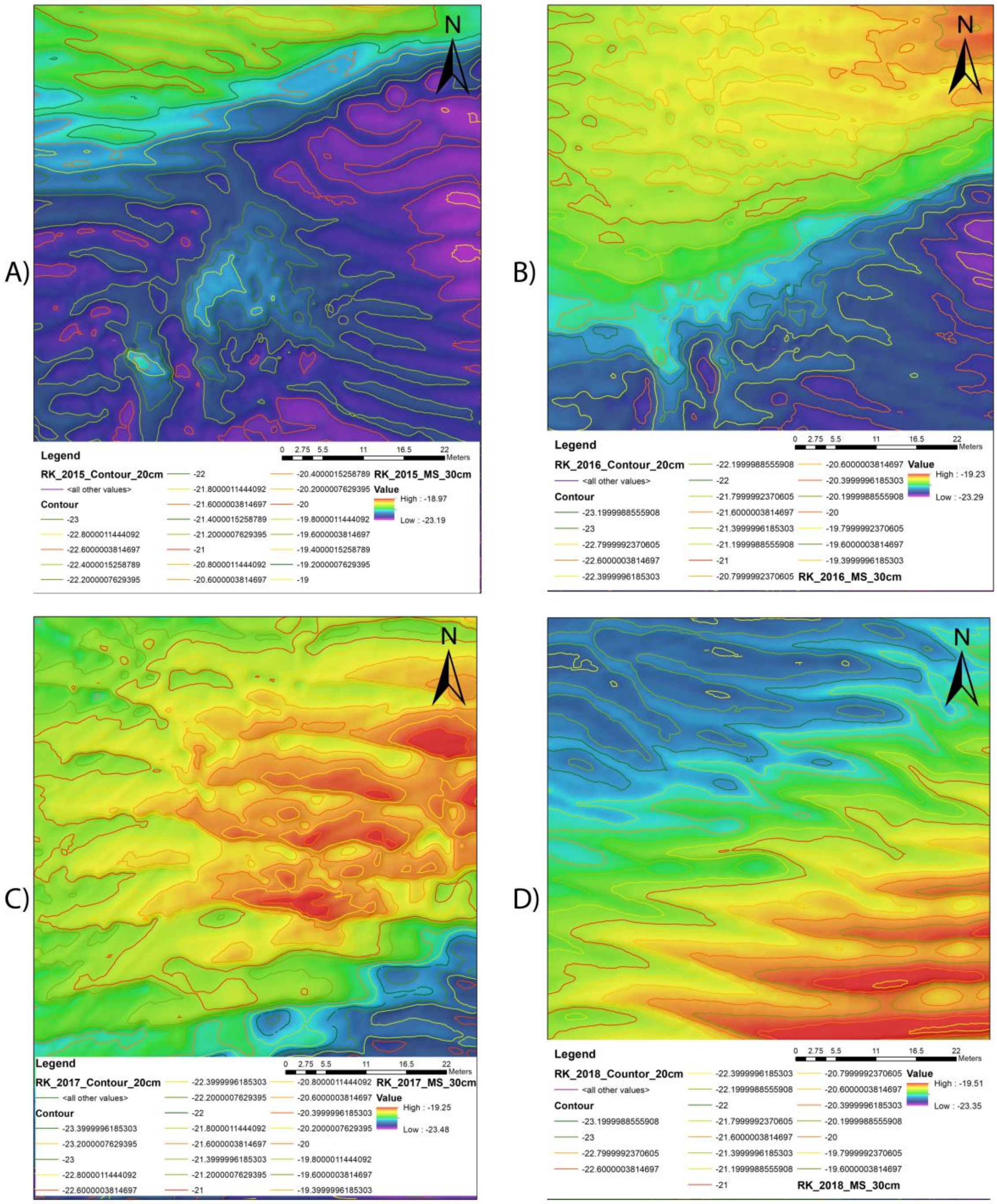

Figure 80. The figure shows a series of MBES surveys of East Site. A) 2015, B) 2016, C) 2017 and D) 2018. The data was kindly provided by PAS, commissioned by HE to manage the Goodwin Sands and Downs MB Survey (PAS 2017)**. A collaborative team including Pascoe Archaeology, MSDS Marine Ltd and Swathe Services carried out the survey. The author of this thesis created the maps in ArcMap 10.5®.**

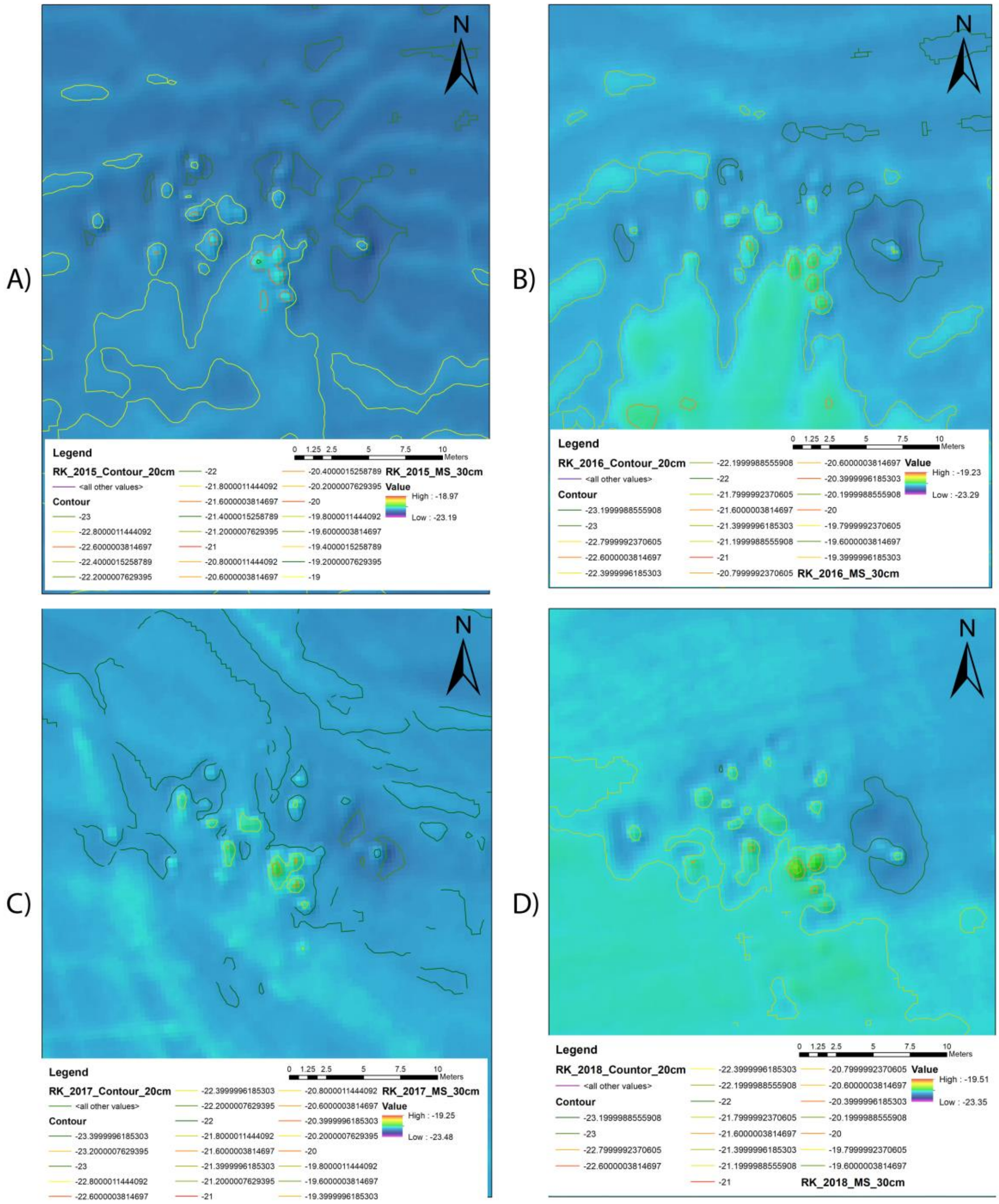

Figure 81. The figure shows a series of MBES surveys of North Site with 20cm contour lines. A) 2015, B) 2016, C) 2017 and D) 2018. The data was kindly provided by PAS, commissioned by HE to manage the Goodwin Sands and Downs MB Survey (PAS 2017)**. A collaborative team including Pascoe Archaeology, MSDS Marine Ltd and Swathe Services carried out the survey. The author of this thesis created the maps in ArcMap 10.5®.**

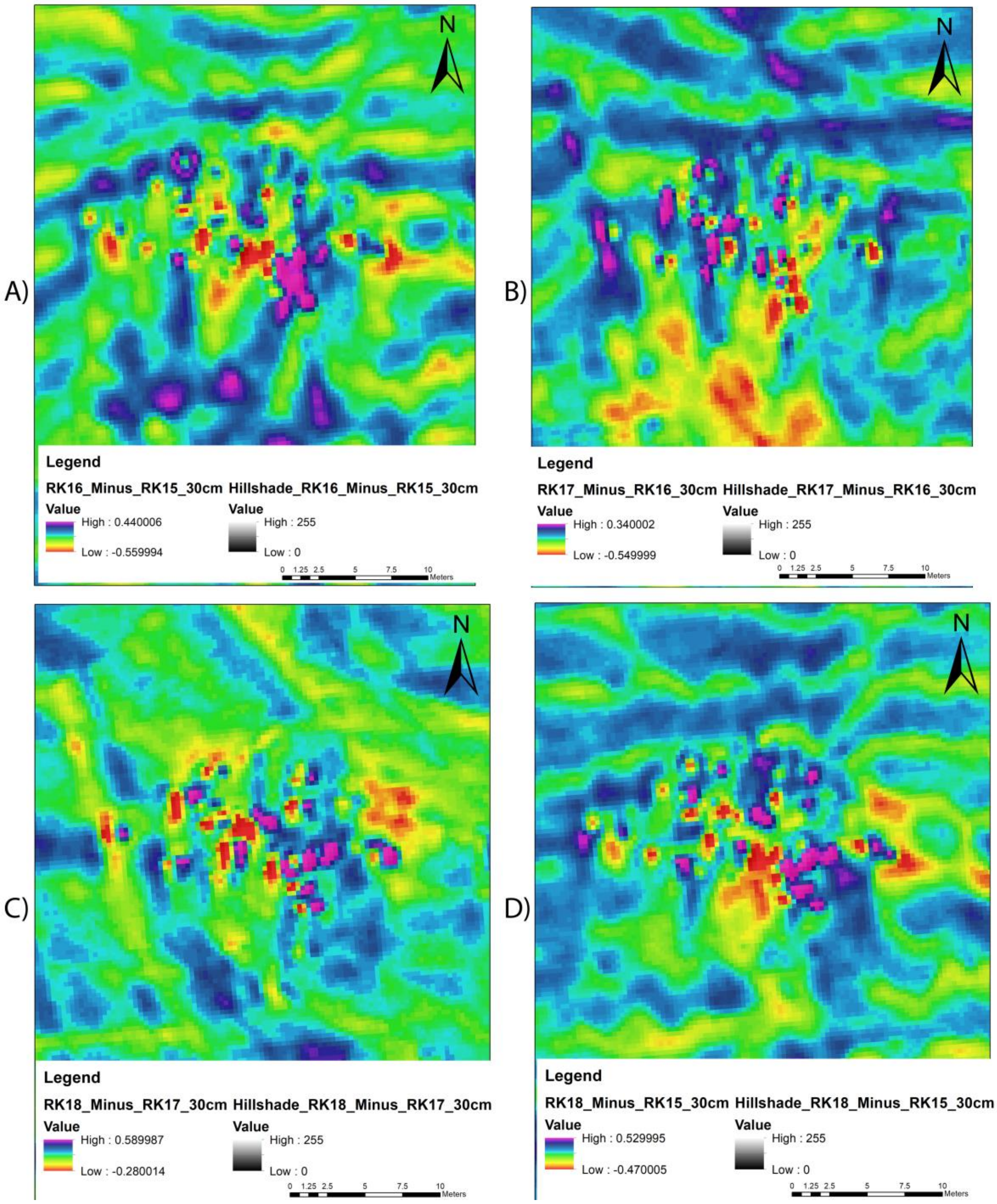

Figure 82. The figure shows a time-lapse series of surveys of North Site. A) 2015-2016, B) 2016-2017, C) 2017-2018 and D) 2015-2018. The data was kindly provided by PAS, commissioned by HE to manage the Goodwin Sands and Downs MB Survey (PAS 2017)**. A collaborative team including Pascoe Archaeology, MSDS Marine Ltd and Swathe Services carried out the survey. The author of this thesis created the maps in ArcMap 10.5®.**

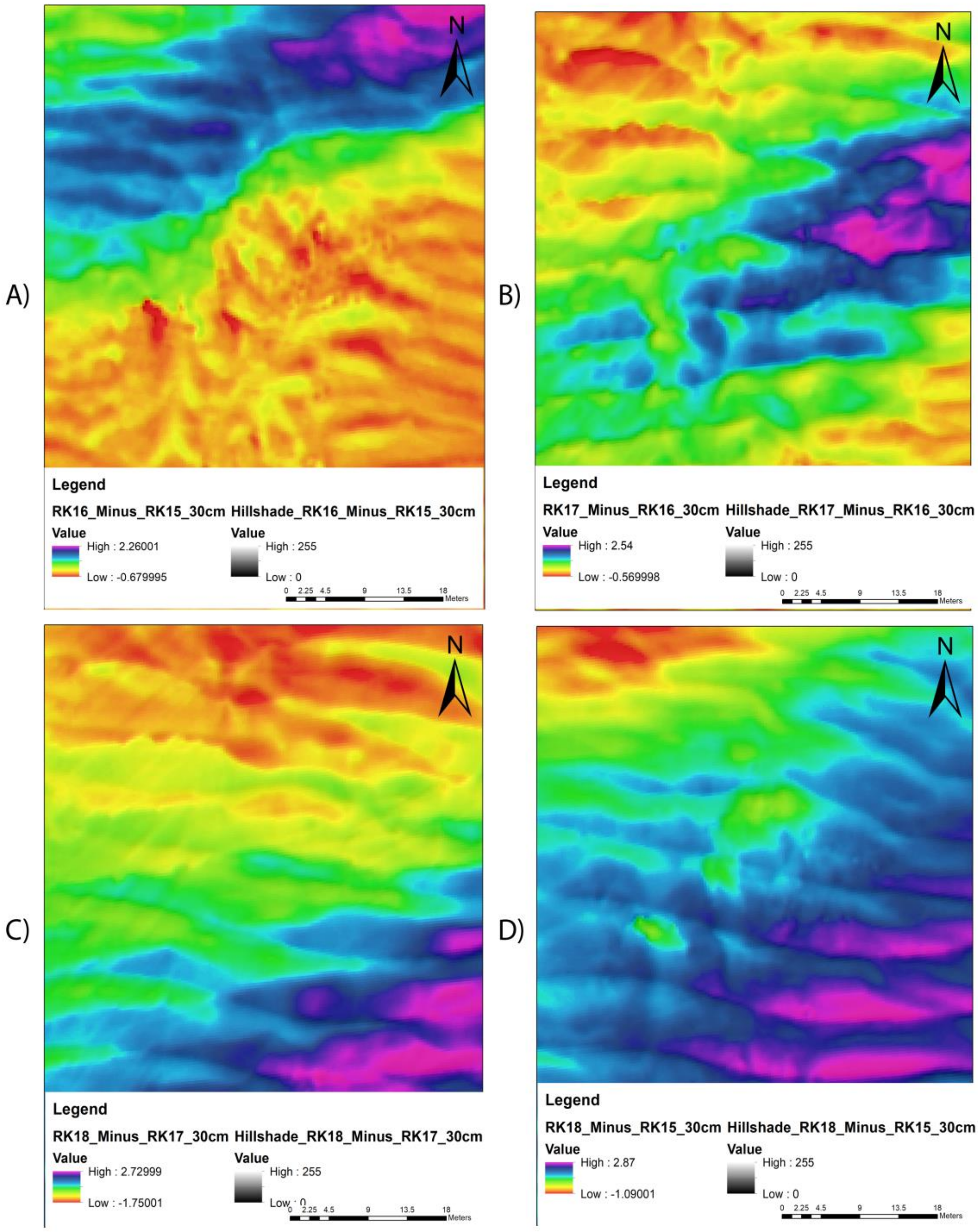

Figure 83. The figure shows a time-lapse series of surveys of East Site. A) 2015-2016, B) 2016-2017, C) 2017-2018 and D) 2015-2018. The data was kindly provided by PAS, commissioned by HE to manage the Goodwin Sands and Downs MB Survey (PAS 2017)**. A collaborative team including Pascoe Archaeology, MSDS Marine Ltd and Swathe Services carried out the survey. The author of this thesis created the maps in ArcMap 10.5®.**

Summary

The remains of the *Rooswijk* lie in the Kellet Gut, between the Goodwin Knoll and South Calliper, spread out into four sites (west, east, north and northeast)[329]. The seabed dynamics of the *Rooswijk* are better understood by observing the morphological changes of the shifting sands that are moved mainly by the tides.

The systematic MBES time-lapse presented in this chapter offers new insights into how the seabed morphology changes on an annual basos. The time-lapse describes how the seabed dynamics affect the *Rooswijk's* scattered site (s), on both mesoscale and intra-site scales.

From the three-year period (2015-2018) and four MBES surveys two main things are noticeable:

1) The southward movement of a medium size sandbank to the east of the main site. This sandbank will continue to migrate south affecting mainly the east site and changing localized tidal movements. This is visible in the sand ripples that run in an east-west direction, in 2018 the spacing between them is greater than in 2015 (Figure 74).

2) The description of the west, east, north and northeastern sites show the complexity of describing intra-site dynamics of a scattered ordered wreck site in a high-energy tidal environment. This localized phenomenon of tidal energy has a direct impact on the general artefact distribution, and in particular on small mobile artefacts. The continued seabed movement affects the preservation of artefacts that are subject to physical, chemical and biological erosion effects. Therefore, the seabed movement description of the MBES time-lapse aids our interpretation of the site formation processes focusing on both

[329] After the excavation of 2017 and 2018, it was tentatively concluded that the remains of the *Rooswijk* are scattered ordered or spread out into four sites (west, east, north and northeast). The artefact distribution is further explained in the following section 6.6.3.

extraction filters and *scrambling devices* [330] and their effects on the archaeological record.

6.6.2 Multi-Image Photogrammetry (MIP)

Multi-image Photogrammetry (MIP) is an ideal method to record structural features and artefacts on the seabed with a high degree of accuracy and resolution[331] at an intra-site level. This technique allows creating 3D models, Digital Elevation Models (DEM) and ortho-rectified images of extensive sites. However, the challenging conditions on the *Rooswijk,* with low light, extremely low-visibility conditions (< 1m[332]), and a very mobile sandy seabed, severely limit the capacity to carry out photogrammetric surveys on site. Luckily, during the 2017 excavation, a few days with 3 m visibility enabled divers to carry out a survey of trench 1 (8 x 4 m), located in the main site (west site). Unfortunately, further attempts of carrying out more MIP surveys were impeded by the site conditions, mainly because of the poor visibility underwater.

The total area of the photogrammetry survey was 57.81m^2, which required several dives to complete due to the challenging conditions[333] (Figure 84, Figure 85 and Figure 86). The Ground Control Network (GCN) was established with the fixed positions of the four corners of the grid with the USBL and recognisable features on

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[330] *Extracting filters* are defined as mechanisms that took material away from the wreck, such as the nature of the wrecking process, salvaging, and disintegration of objects (Muckelroy 1978:165-169; Stewart 1999:567). *Scrambling processes* include the wrecking and post-depositional processes that are governed by the environments energy-level, waves, currents, seabed movement, and bioturbation (Muckelroy 1978:169-182; Stewart 1999:567).

[331] The Rooswijk 1740 Project followed strict Health & Safety Executive (HSE) standards, with Diving at Work Regulations (1997) and the appropriate Approved Codes of Practice Guidelines (HSE 1997b, 1997a). The excavation was carried out with a vessel permanently anchored on site with a four-point mooring allowing lowering the basket/wet bell straight on top and maintaining position.

[332] During the 2017 excavation, many dives where carried out in 200-300 mm on visibility.

[333] The main challenge of working underwater on the Rooswijk site is the short windows in terms of diving, because of the depth, short slack tides and low visibility (average <1 m). The low visibility restricted taking pictures and carrying out photogrammetry surveys.

the MBES surveys, giving x (easting), y (northing) and z (depth) values for each point in WGS 84 Zone 31N.

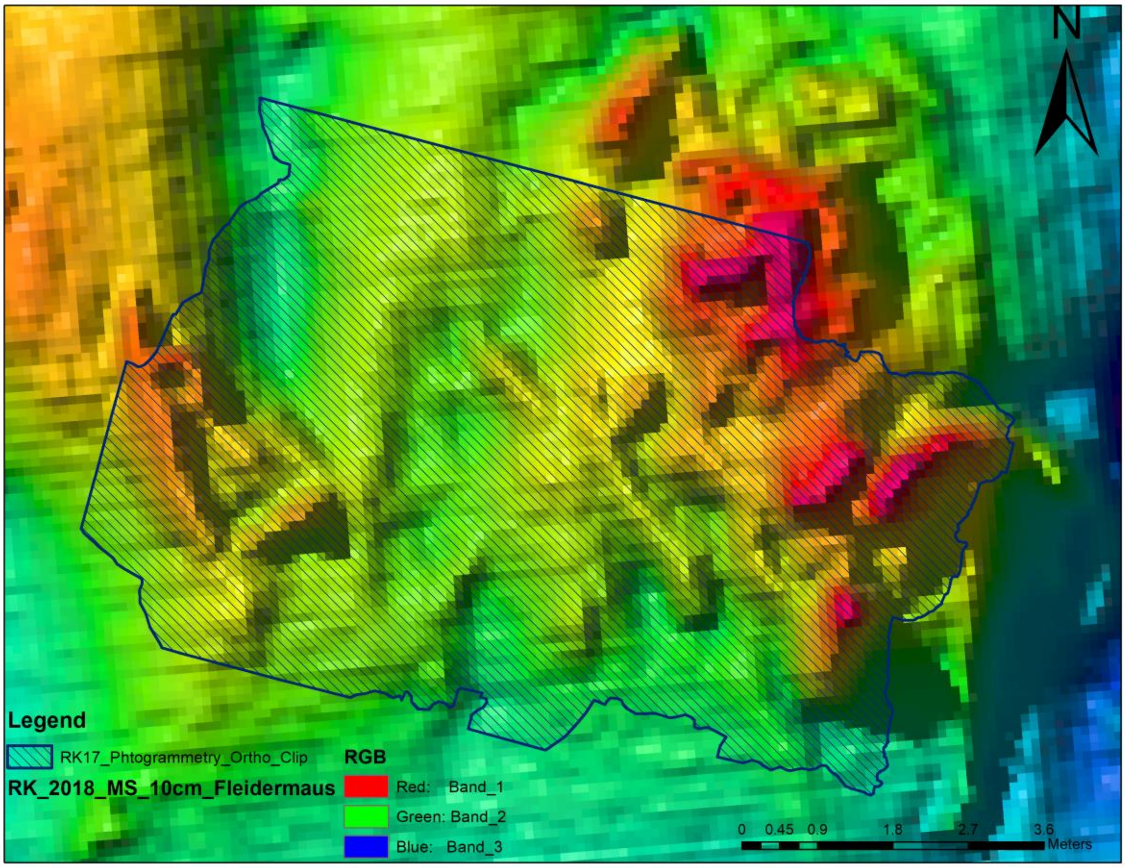

Figure 84. The figure shows the coverage area of the photogrammetry survey, 57.810522m^2. The survey area is overlaid on top of the MBES survey from 2018. The data was kindly provided by PAS, commissioned by HE to manage the Goodwin Sands and Downs MB Survey (PAS 2017). **A collaborative team including Pascoe Archaeology, MSDS Marine Ltd and Swathe Services carried out the survey. The author of this thesis created the map in ArcMap 10.5®.**

The orthophoto presents a high-resolution survey of the central area of the mound on the main site (west site). Most of the artefacts found in this area are heavy materials such as building blocks, spare anchors (stacked together), copper sheets, lead rolls, chests[334] and a large concretion with several artefacts amalgamated together (Figure 89). There are a few scattered timbers in the area as well, a large floor timber in the middle and possibly a part of the Keel/Keelson known because of a scarfed joint and the dimensions (Figure 85 and Figure 86). Some of the features are more easily visualised with a top-down rendered model in 3DsMax® (Figure 86).

[334] The content of the chest is still unknown, as they are going through conservation process. Based on the size of the chest's and previous experience from 2005, they probably contain swords (*pers comm* Hildred, and Pascoe).

During the 2018 excavation, several timbers (frames) were discovered underneath the two anchors[335]. These frames were exposed due to the erosion of the sediment around the anchors and the southern area observed in the MBES time-series[336]. The survey produced a high-resolution DEM that can be used in a time-series to understand intra-site scale sediment migration in the future. The DEM also provides valuable diagnostic tools to understand the difference in depths around the main site, within 58 m^2 (Figure 86).

The artefacts found inside of Trench 1 are heavy cargo that would be found in the bottom of the ships' hold. The few structural features found in the area, floor timbers, frames, and possibly a part of the keelson (Figure 88 and Figure 89)

[335] Unfortunately, site condition impeded another photogrammetric survey of the same area during 2018. This might happen during 2019, providing an intra-site comparative survey.

[336] MBES survey for *Rooswijk* are explained in section 6.6.1 of this chapter.

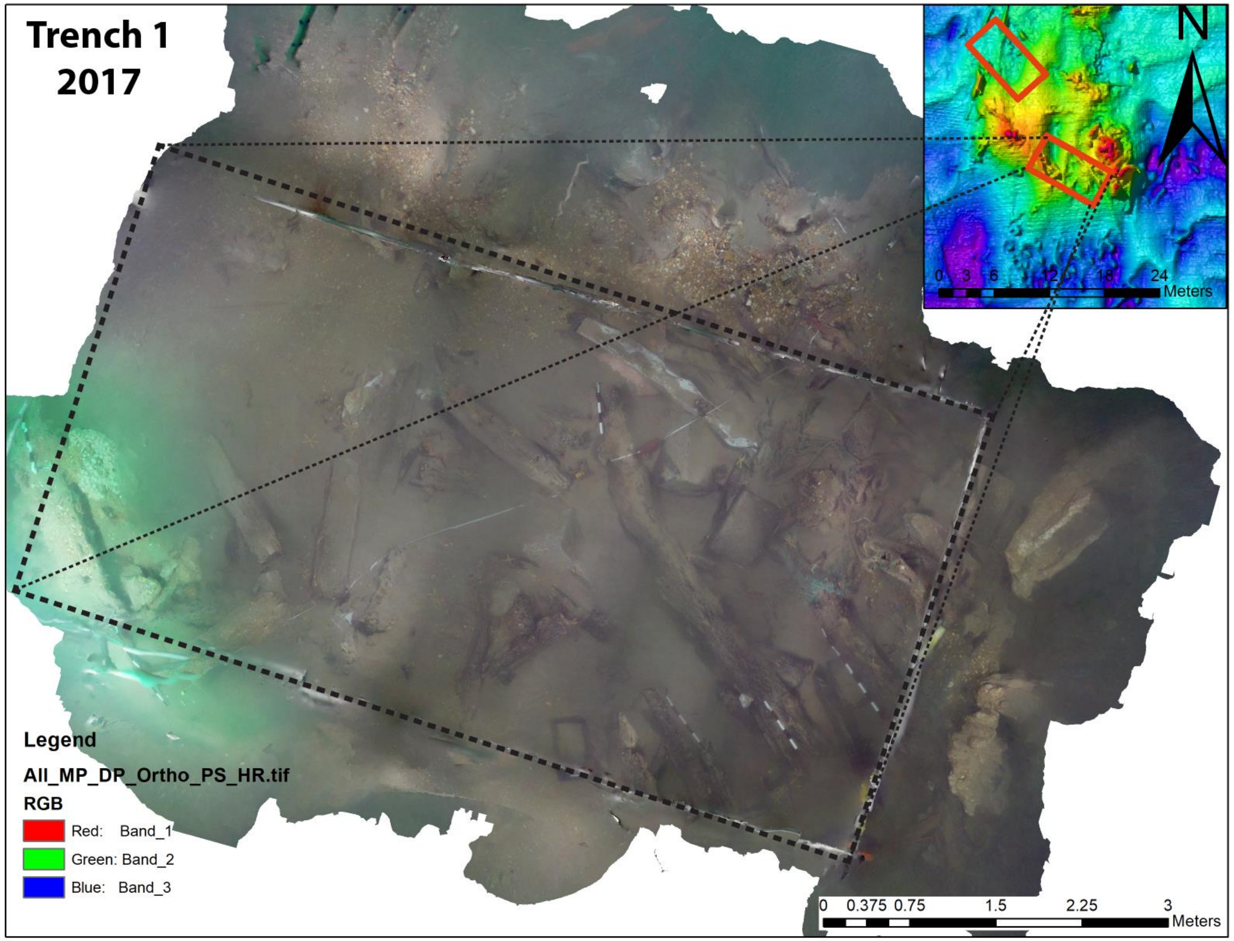

Figure 85. The figure shows an orthophoto made by the author of this thesis, with Agisoft Metashape Pro v1.5 ®. The use of this image is kindly provided by the Rooswijk 1740 Project. The author of this thesis created the map on ArcMap 10.5®.

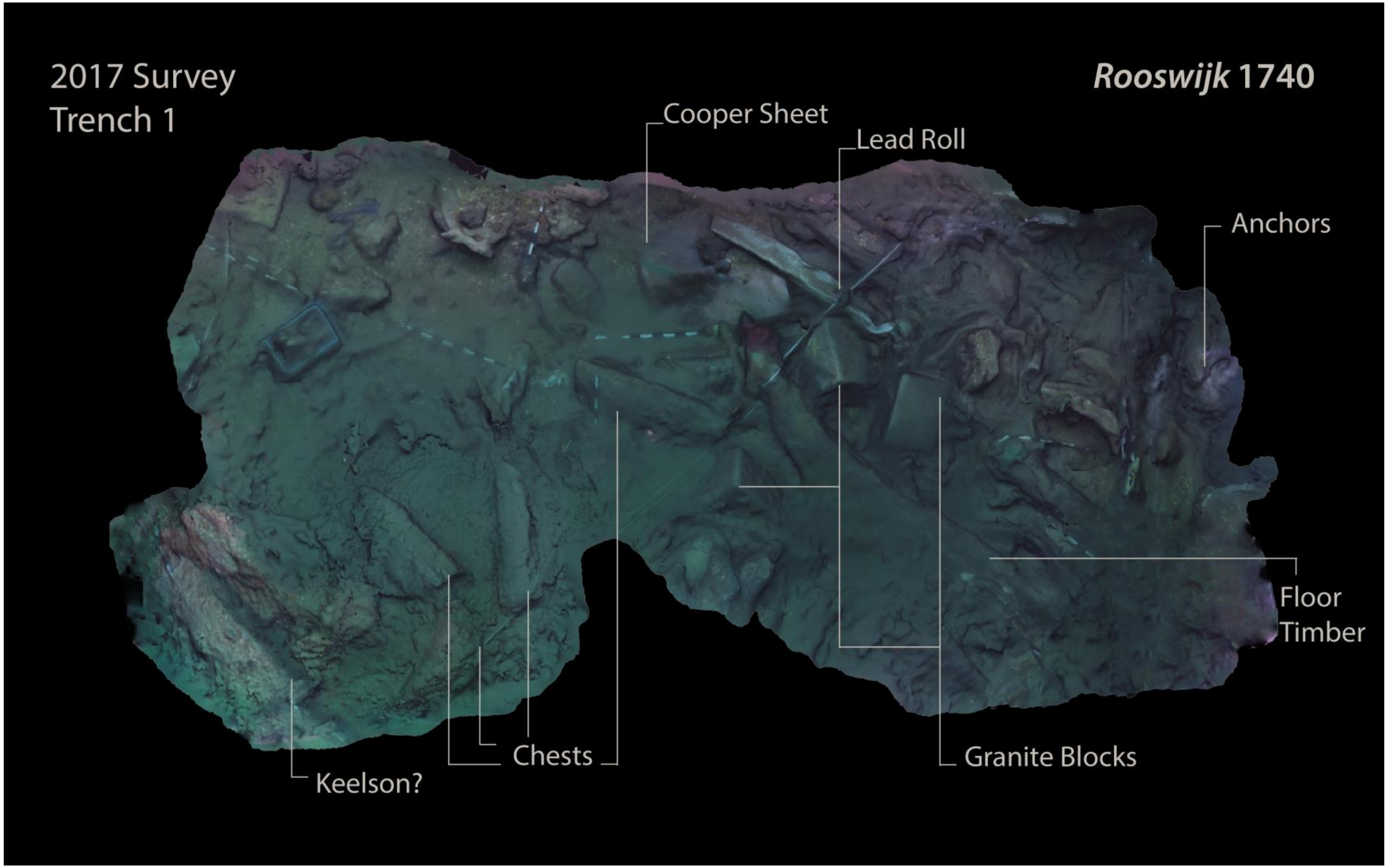

Figure 86. The author of this thesis processed the photogrammetry survey with Agisoft Metashape Pro v1.5 ®. The image was rendered in 3dsMax®. The author of this thesis created the figure.

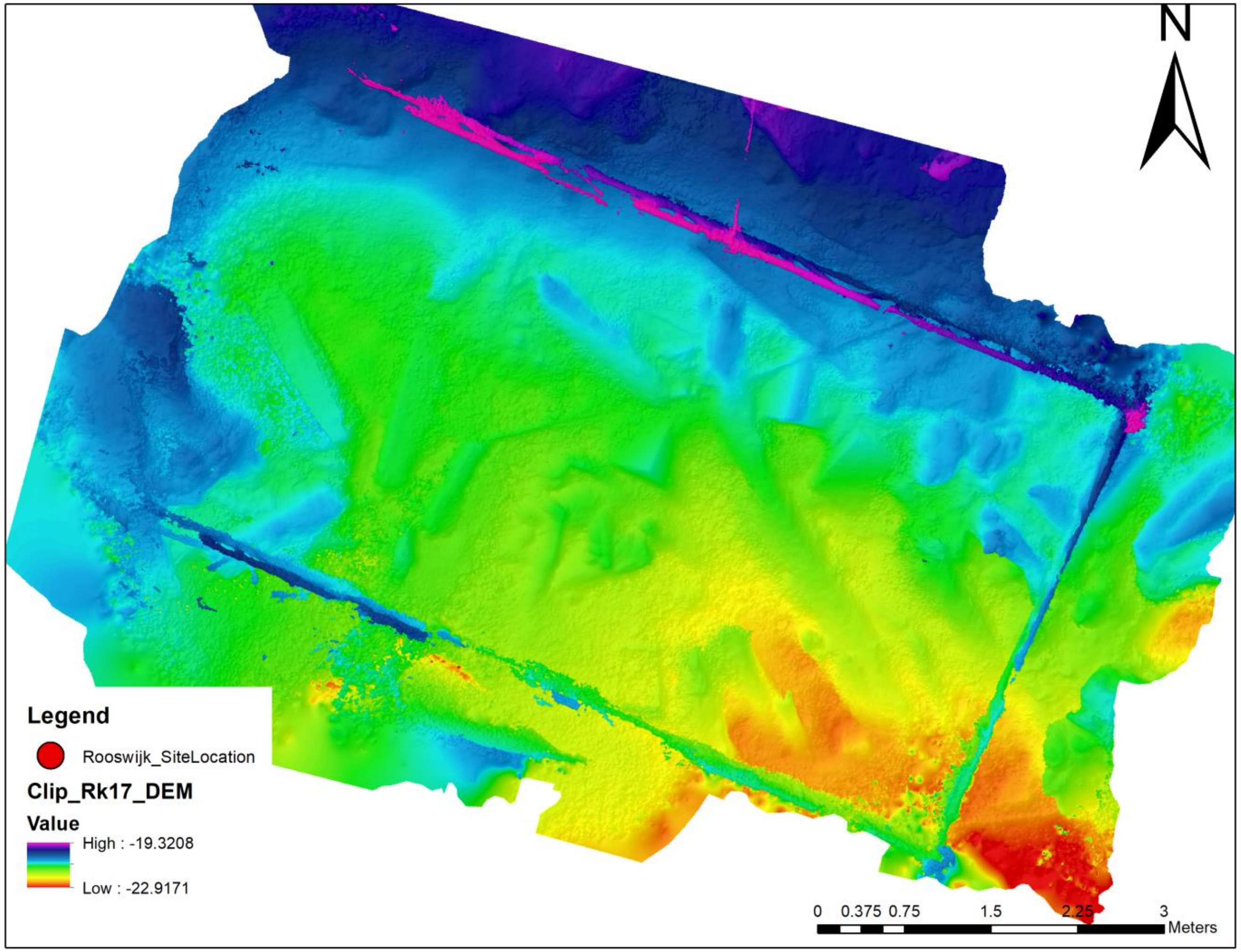

Figure 87. The figure shows DEM made with Agisoft Metashape Pro v1.5 ®. The area is overlaid on top of the MBES survey carried out by MSDS Marine in 2018, kindly provided by PAS. The author of this thesis created the map in ArcMap 10.5®.

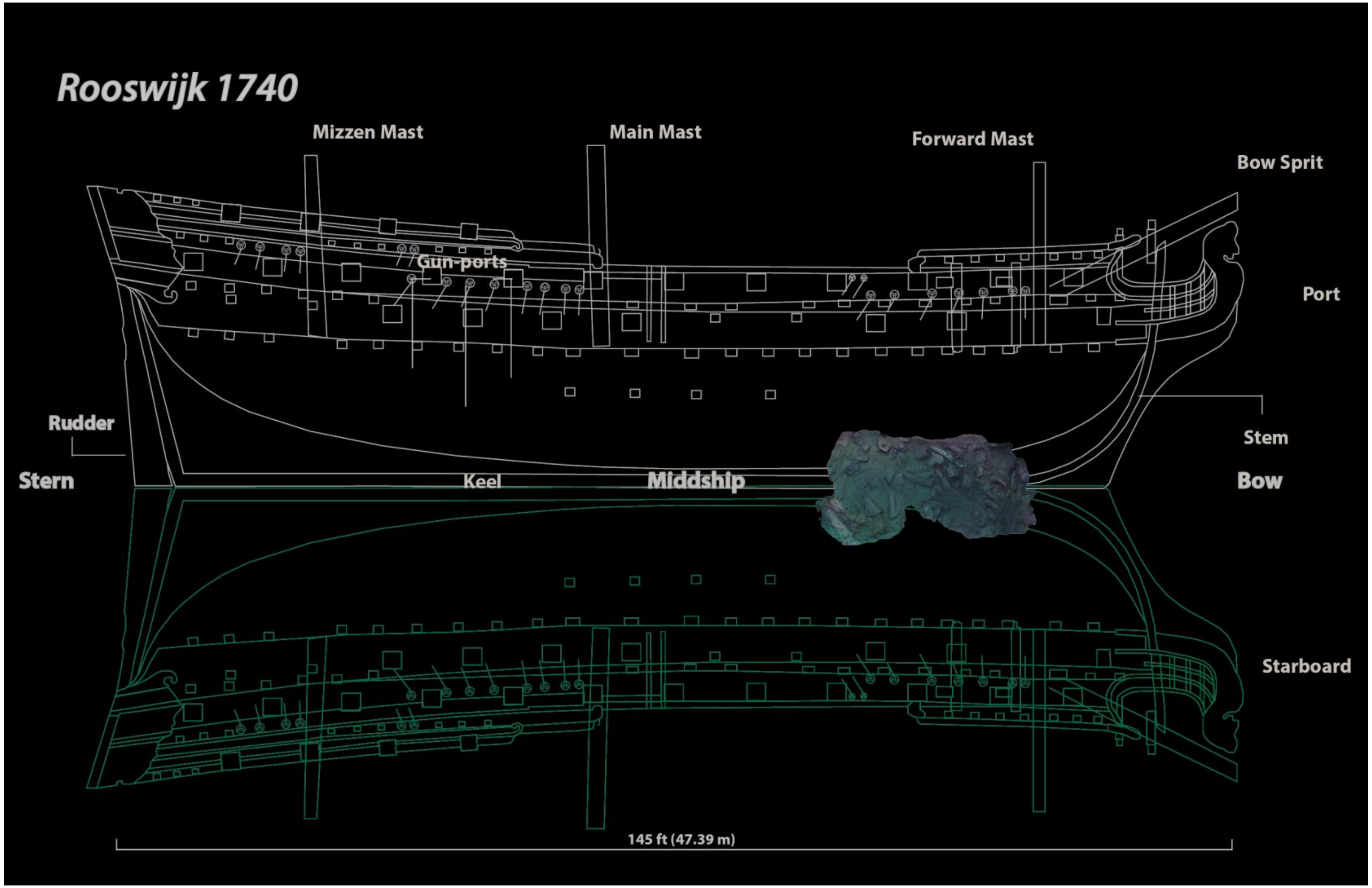

Figure 88. The figure shows the possible area surveys in 2017 with photogrammetry of the main site (West site). The lines plan was based on drawn by Bentam for VOC ships (Bentam 1742b)**. The author of this thesis created the image.**

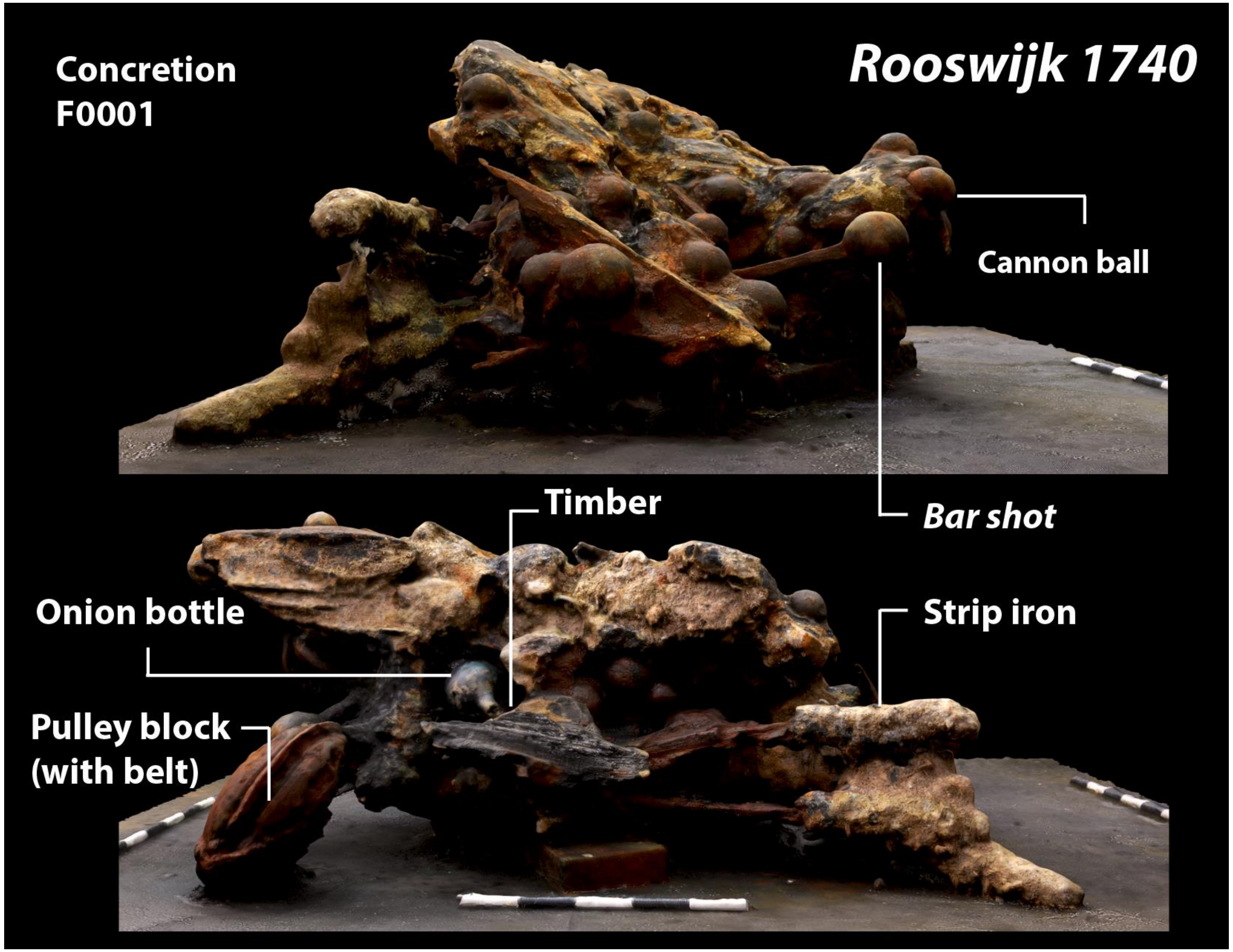

Figure 89. The figure shows a large concretion recovered from Trench 1 that was disarticulated into individual artefacts. The author of this thesis recorded the artefact and rendered the images in 3dsMax®. The images are used with the kind permission of the *Rooswijk* 1740 project.

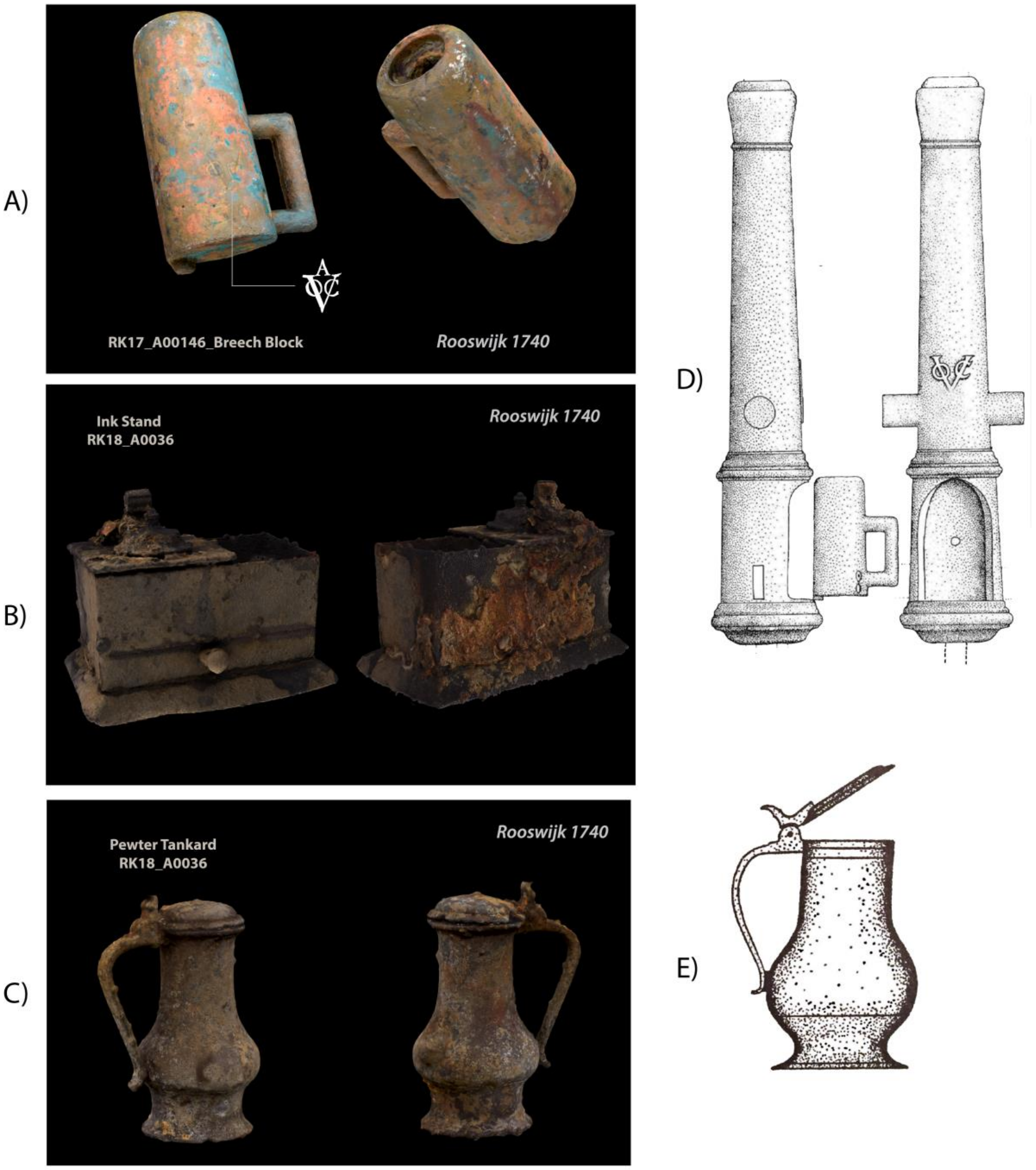

Figure 90. The figure shows a selection of artefacts. A), Breech block, B) Inkstand, C) Pewter tankard, D) Breech block, illustration modified from (Duivenvoorde 2010:44) **and E) Pewter Tankard, illustration modified from** (Marsden 1974:133)**. The author of this thesis recorded the artefacts and rendered the images in 3dsMax®. The images are used with the kind permission of the *Rooswijk* 1740 Project**

6.6.3. Ultra-Short Base Line (USBL)

The *Rooswijk* wreck site conditions with mobile sediments, strong tides, poor visibility and short diving windows required a quick and accurate method of recording artefacts' positions underwater during the excavation. The use of traditional methods (direct measurement, trilateration or direct survey measurement) were both inadequate and inaccurate considering the compound error of using tapes underwater. The SCOUT Ultra-Short Base Line (USBL) by Sonardyne HF (35-55 kHz) was the ideal method to track, locate and record the position of individual artefacts on the *Rooswijk*, with a 0.5 % slant range accuracy (+/- 20 cm at 22/24 m depth) (IMCA 2016; SONARDYNE 2012).

6.6.3.1 Spatial Distribution and Artefact Classification.

During the excavation on the *Rooswijk* in 2017 and 2018, the diving team used an offshore surface supplied setup, which provided constant communication between the divers and topside[337]. This enabled the topside team, to use the live tracking system (USBL) to orientate the diver, take position fixes and plot artefacts on a GIS platform: Site Recorder 4 ® (3H 2006). The database and maps were updated on a daily basis depending on the number of artefacts recovered per dive during the fieldwork. However, database post-analysis is required to ensure that every artefact is plotted, as some artefacts are recovered in "clusters" when they are concreted[338] (Figure 89). This section presents the artefact distribution found during the 2017 and 2018 excavation.

Spatial distribution analysis on a shipwreck can be broken down into different stages and scales of study (macro, meso and intra-site). As explained at the beginning of this chapter, on a macro scale, the *Rooswijk* is one of the hundreds of identified wrecks that have sunk in the Goodwin Sands. On a mesoscale, the *Rooswijk* has four wreckage areas that have been clearly identified: east site, west site or main site, north site and

[337] Top side, is normally a diving supervisor working along with the archaeologists from the vessel, that are in constant communications with the divers underwater, with a two way communication system and video.

[338] A concretion is a stone-like encrusted clump or conglomerate created by the natural elements around an artefact, often rusted iron. A concretion could contain a mix of organic and inorganic material. Follow the link for an example (https://skfb.ly/6toAo).

northeast site (Figure 73). Pre-disturbance and Post-disturbance surveys are a common practice to analyse the general distribution of large artefacts found on the seabed such as guns, anchors, ships' structure, ballast, large cargo, or concretions. By mapping them out it is possible to have a layout of the wreck, and determine whether the distribution is coherent, scattered ordered or scattered disordered.

The first systematic underwater excavation on a shipwreck at Cape Gelidonya, mapped out meticulously the general distribution of site and its artefacts, to understand its wreck-formation process (Bass 1961, 2012). In the Mediterranean several other wrecks were surveyed and mapped out extensively, to mention a few: *Yassiada* (Bass and van Doorninck 1982) *Uluburun* (Bass et al. 1989; Pulak 2008), *Kyrenia* (Steffy 1985) and *Madrague de Giens* (Tchernia, Pomey, and Hesnard 1978). Similarly, in the British Isles, *El Gran Grifón* (Martin 1972) *Trinidad Valencera* (Martin 1979) *Dartmouth* (Martin 1978), and *Adeelaar* (Martin 2005). Without forgetting others some of the VOC wrecks in different corners of the world, *Vergulde Draeck* (Green 1973), *Rockley Bay Research wrecks* (Batchvarov 2016), *Batavia* (Baker and Green 1976; Van Duivenvoorde 2008; Van Duivenvorde 2015) and the *Hoorn* (Murray et al. 2003)[339]. However, Muckelroy was the first to systematically observe micro-distributions within the areas excavated that showed a strong correlation between the seabed and shipboard associations (Muckelroy 1975, 1976b:286–87). Although these wrecks were recorded to the last detail, they all lacked a critical analysis, of the surrounding environmental conditions gained by integrating remote sensing techniques such as on the *Invincible* (Ortiz-Vázquez 2013; Quinn et al. 1998), *Mary Rose* (Quinn, Bull, and Dix 1997), *Yarmouth Roads* (Plets et al. 2008), *Stirling Castle* (Astley et al. n.d.), or *Fougeaux* (Fernández-Montblanc et al. 2016).

Shipwrecks with an extensive remaining structure and a coherent distribution, allow moving from mesoscale to an intra-site scale with distinct activity areas. A few examples are the *Mary Rose* (Marsden 2003; McElvogue 2015; Rule 1982), *Amsterdam*[340] (Gawronski 1990; Marsden 1974), *Reb Bay* (Bernier 2007; Parks Canada 2007), *Vasa* (Hocker 2011), *Mars* (Eriksson and Rönnby 2017), HMS *Erebus* and HMS

[339] Full list of VOC wrecks that have been excavated found in Appendix II. Rooswijk. The list is based on (Van Duivenvorde: 144-145).
[340] *Idem*

Terror (Parks Canada 2018) or the Black Sea wrecks (National Geographic 2017; University of Southampton 2017). Understanding the relationship between artefacts' distribution, structural remains and the use of space can be relatively straightforward with extensive ships' structure. The greatest example in British waters of an extensive excavation of a wreck is undoubtedly the *Mary Rose*, where over 19,000 objects have been recovered from the wreck site (Mary Rose Museum 2018). A great deal of publications with detailed plans of the ships' structure and thorough analysis has been made on its artefacts (Adams 1988; Marsden 2003; McElvogue 2015; Rule 1972, 1982). The *Mary Rose* museum has managed to explain successfully the use of space and the activities carried out on board a Tudor ship. Yet, on the other side of the spectrum, a scattered wreck without a coherent structure represents a completely different challenge. As Muckelroy pointed out over 40 years ago, less attention has been focused on sites where the remains have been scattered widely over the sea-bed, and no coherent ship's structure has survived (Muckelroy 1975:188). Muckelroy observed that micro-distributions within the areas excavated also show a strong correlation between the seabed and shipboard associations on the *Kennermeland*[341] (Muckelroy 1975, 1976b:286–87). He recognised the possibility of finding associations with meticulous recording and scientific analysis with the tools and methods available during his time.

In this chapter, the *Rooswjik* represents a great challenge of interpreting its site formation process, because the wreck has no remaining any coherent structure, and it is scattered in areas within a radius of 250 metres (Figure 73). Moving from the smallest unit of archaeological analysis that can be found in an individual artefact, or an assemblage of them, followed by the interpretation of their spatial distribution.

The intra-site scale artefact distribution of the wreck of the *Rooswijk* is only possible at the west site (main site), because it is the only area that has been excavated systematically so far.
To explain the artefacts' distribution and their shipboard associations on the *Rooswijk*, it was convenient to create two main categories. The first included all the artefacts, and

[341] The *Kennermeland* 1664 is a VOC ship that wrecked off Stoura Stack, Out Skerries in the Shetland Islands, Scotland.

the second is specie[342] subdivided into different types of currency. This arbitrary classification was made due to the amount of specie, its variety and the distinctive distribution found across the site. Separating the specie from the rest of the artefacts aids in establishing the spatial distribution pattern that could add to our understanding of the post-wrecking process. The captain's cabin, found at the stern of the ship was the storage space for the valuables. Therefore, by establishing the distribution of the specie, it would be possible to deduct the area in which the stern was disarticulated. The artefacts were classified into the following classes:

- Artefacts (Figure 93)
    - Tools or equipment (Tool handles, thimbles, oil lamps, anchors, sounding lead, inkstand (Figure 90 (B), candleholders, candlesnuffers, dividers, etc.).
    - Ship fittings (Rigging blocks (Figure 89), structural timbers, chain, chain plates, sheathing, gun port lid, rudder pintle, etc.).
    - Ordnance (Guns, shot, muskets, pistols, breech blocks, etc. (Figure 90 (A)).
    - Domestic (Spoons, bowls, sups, dished, flagon, jars, jugs, pots, lamp, tankards (Figure 90 (C), syringes, jug, knife, clay pipe, etc.[343]).
    - Food (Barrels with salt pork, cheese container, and onion bottles with wine, etc.).
    - Clothing (Buckles, shoes, buttons, etc.)
    - Cargo (Raw materials, copper sheet, lead role, granite blocks, barrels, bottles, boxes, bricks, chests, etc.)
    - Human Remains (Bones)
    - Miscellaneous (CU Rings[344], strip iron, concretions (Figure 89)

- Specie (Figure 94) [345]

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[342] Specie is money in the form of coins rather than notes. VOC ships are known for having large quantities of specie used for their trading affairs.
[343] Full animated video with Pewter artefacts available at https://vimeo.com/282860826.
[344] Possibly used for chainmail or to back a pouch.
[345] Metallic money (coins, precious metal, silver bullion, etc.)

- Dutch (Figure 95)
  - Stuivers
  - Rijders
  - Ducaton
- Spanish (Figure 96)
  - Pillar Dollar
  - Cobs
  - Mixed Specie

The historical records do not account for the complete amount of the artefacts, cargo, tools, equipment, provisions, ordnance and specie officially carried on the *Rooswijk.* As pointed out by Martin, specie was supplied to VOC ships by outside contractors, so bills of lading[346] which specify the detailed make-up of consignments were not held by the Company, and consequently do not survive in its records (Martin 2005:197; Pol 1986). However, a recent investigation of public record in the Netherlands indicate that 37,282 guilders, 10 stuivers and 70 ducatons were loaned to several crew members before their last trip on the *Rooswijk*. The deeds of these cash loans are all bonds, that is to say, debts, in which the 'person appearing' declares that he owes a sum of money to the lender (Van Grondelle and Vermij 2018:18). It is known that smuggling was a widespread practice by the crew members on board VOC ships (Pol 1986:586). Therefore, it is possible to find evidence of this practice in the archaeological record, by distinguishing it from the official specie on board. However, it is important to understand that the artefacts that were excavated in 2017 and 2018 are only a small representation of the abundance of trade-goods found on a VOC ship and that the material recovered during the excavation has been subject to *scrambling processes* due to the dynamism of the environment and *extracting filters* from previous excavations[347].

[346] The action of loading a ship with cargo.
[347] *Extracting filters*, defined as mechanisms that took material away from the wreck, such as the nature of the wrecking process, excavation, salvaging, and disintegration of objects (Muckelroy 1978:165–69; Stewart 1999:567). *Scrambling processes* that begin during the process of wrecking. This included the post-depositional wrecking processes that are constituted of physical (waves, currents, seabed movement), chemical and biological erosion (Muckelroy 1978:169–82; Stewart 1999:567).

The VOC not only standardised shipbuilding techniques for the construction of *retourschepen* destined for Batavia but also the supplies, equipment, storage and materials carried on board. The standardisation of storage of specie on board, on the *Hollandia, Liefde, Meresteyn, Adelaar* and *Amsterdam*[348] is relevant for understanding practices on other VOC ships such as the *Rooswijk.* The composition of the specie on the *Rooswijk* is interesting for its multinational currency (Dutch and Spanish), as it represents a globalised modern world network of trading routes, economy, power, politics and social behaviour.

The Dutch specie found of the *Rooswijk* are of three main types ducaton (71[349]), rijders (293), and stuivers (288) (Figure 91).
The silver ducatons ranged from 1619 to 1662, and they varied in these periods. The earliest coins found on the wreck were from the Spanish Netherlands[350], minted in Brussels in 1619. These coins bear the portraits of the governors: the Archduke of Austria and Isabella Duchess of Brabant. Another type of ducaton, were minted in Bruges or Antwerp bearing Philip IV (1621–1665)(Figure 95 (A and C))[351]. Another type of ducaton bares a portrait of Charles II (1665-1700), minted in Antwerp (Figure 95 (B)).
The second type of Dutch specie is the Rijder ranging from 1676 to 1739[352], minted in Brussels.
The third type was the stuivers, with a value of 60 for one ducaton. The date of the coins found on the wreck range from 1673 to 1690 (Figure 95 (D)).

The Spanish specie found on the *Rooswijk* are of three main types, pillar dollars (180[353]), cobs (513) and klippes (1) (Figure 91). The 8-reales or pillar dollars were of

[348] Full list of 50 VOC excavated shipwrecks in Appendix II. *Rooswijk* (based on van Duivenvoorde 2015:144-145).
[349] Quantity found during the excavation of 2017 and 2018.
[350] These coins where from the Duchy of Brabant that belonged to the Spanish Netherlands (c.1579-1713). The Spanish Netherlands under the Habsburg consisted of most of present day Belgium and Luxembourg.
[351] See an example https://skfb.ly/6tVXB).

[352] 249 found dated to 1739, probably made or acquired for the trip. See an example https://skfb.ly/6tVXy.

[353] Quantity found during the excavation of 2017 and 2018.

Spanish-American origin, also called "Mexicans"[354] by the Dutch (Marsden 1978:142). The pillar dollars found on the wreck range from 1732 to 1738, bearing the coat of arms of Phillip the V, and minted in Mexico City[355] (Figure 96 (A)) (Banco de Mexico 2018:5). Also less common but present in the wreck are 4-reales, with the stamp design but only half the weight in silver with a number explicitly showing the value.

The second type of specie was the cob or *macuquina,* they could be pieces of eight or four[356] (Figure 96 (B and C). The cobs found on the wreck range from 1729 to 1733, and they bear the coat of arms of Phillip V; the assayers and mints varied but most are from the mint in Mexico City[357].

The third and rarest type of specie found on the wreck is called klippes or *recortadas* (the Spanish word for clipped), as they were struck with aligned die to set a fixed axis, including the cobs (Ponterio 2006:vii)[358]. The klippes found on the *Rooswijk* range in date from 1733 to 1734 (Figure 96 (D)).

In 2005, a large amount of the specie was recovered, but we are uncertain of their spatial distribution, therefore they are not included in this chapter (Ponterio 2006). However to understand the size of the sample that is being analysed on the *Rooswijk,* from the excavation of 2017-18, it is important to consider the analysis of three almost contemporary VOC wrecks in British Waters, the *Adelaar* 1728, the *Hollandia* 1743, and the *Amsterdam* 1749 (Cowan et al. 1975; Gawronski et al. 1992; Marsden 1974, 1978; Martin 2005).

The bulk of the specie on the *Amsterdam* 1749 comprised of 1200 silver bars, each weighing 8-mark[359] or 1.969 kg (4.34 lbs) (Marsden 1978:141; Zevenboom 1956:50).

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[354] Prior to 1732 the Spanish-American reales took the form of cobs, irregularly shaped, or some- times round or square, flat pieces of silver which had been clipped to the correct weight, but as over-clipping was possible at any stage the cobs could be underweight and were thus unsatisfactory. See and example https://skfb.ly/6tpNZ
[355] In 1536, the Mexico City mint became the first mint to produce coins in the New World. The mint used the method of hammering coins by hand, known as cobs (Banco de Mexico 2018:5).

[356] See an example https://skfb.ly/6trqw.
[357] A few rare examples found in 2005 came from the mint of Potosi (modern day Bolivia) and Guatemala.
[358] The klippes where made prior to the arrival of new equipment to Mexico City, the first milled coins or "Pilllar Dollars" were struck in March 29th 1732.
[359] 1 mark = 0.246084 kg

A single chest would contain 50 ingots; each chest contained 984 kg (216.9 lbs) of silver. In the case of the *Rooswijk,* most of these bars were recovered during the previous excavations in 2004 and 2005 and none found in 2017-2018. The remainder of the specie of the *Amsterdam* comprised 16,000 ducatons. It is documented that these had been stored in four chests, each chest containing 4000 ducatons and packed into 20 bags, each of which held 200 coins (Marsden 1978:142). Another 200 pillar dollars were to be used as cash for the ship's expenses during the long voyage.

The *Hollandia* 1743 was carrying about 36,557 pillar dollars of eight-reals, 8,000 full ducatons and an additional 300 eight-real coins as cash for the voyage. It is estimated also estimated that 4000 coins were stored per chest (Marsden 1978:144).

The *Adelaar* 1728 carried 500 8-mark bars of silver, six bars of gold, 32,000 silver ducatons minted that year at Middelburg, and 450,000 copper 2- stuiver coins (Martin 2005:196). In contrast, the *Meresteyn* 1702 (Marsden 1976:211–19) was only transporting Dutch ducatons and no Spanish specie. Quantities and type of specie depended on the demand of silver in Dutch colonies, as well as the availability of resources.

During the 2017 and 2018 excavation, 180 Pillar Dollars[360], 293 Rijders, 71 Ducaton, 288 Stuivers, 513 Cobs, and one Klippe were recovered, giving 1346 in total (Figure 91). Therefore, if the *Rooswijk* were transporting similar amounts of specie to the *Hollandia, Adelaar* or *Amsterdam* the material recovered in 2017-18 would only be a 5-10% of the total, without considering smuggled money.

[360] The pillar dollars were found less concreted to each other, than the ducaton. Probably because of the quality of the Mexican silver.

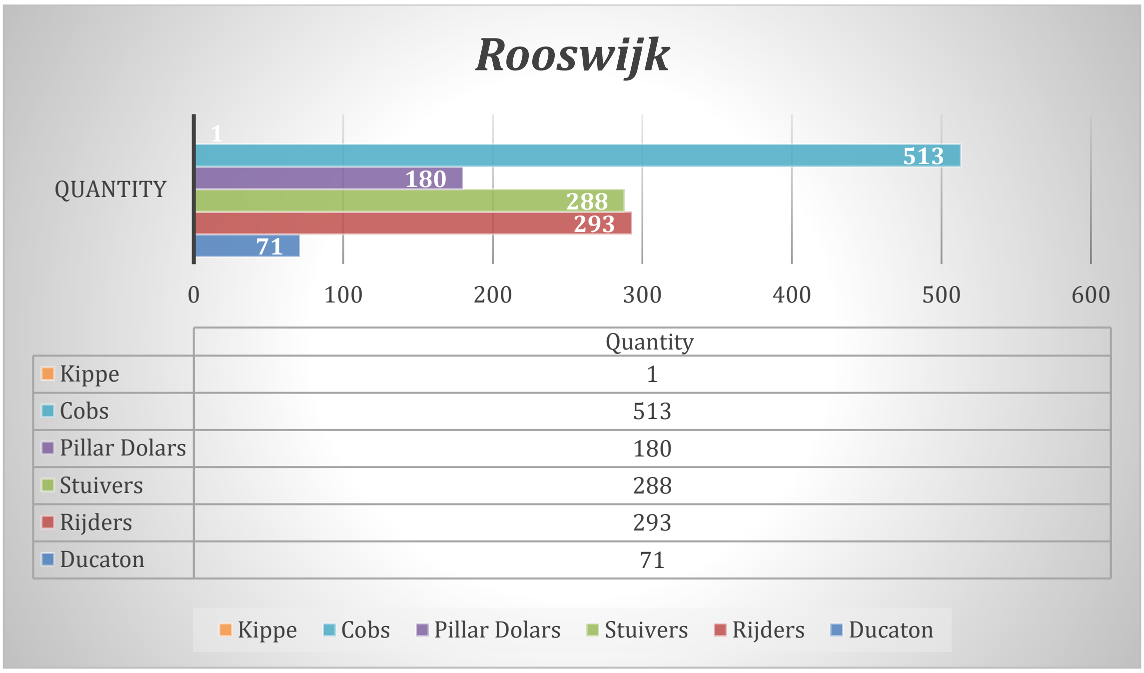

Figure 91. The figure and chart present each type of specie and the quantity found during the excavation of 2017 and 2018. The data was kindly provided by the Rooswijk Project 1740.

A full analysis of all the specie still needs to be done on the *Rooswijjk,* similar to the *Amsterdam, Hollandia* and *Meresteyn* (Marsden 1976, 1978). Including mints, dates value, amount and percentage of the specie recovered during 2017 and 2018.

No other wreck has presented the spatial distribution of these coins to understand the distribution of a wreck with no structure and provide a diagnostic tool for the wrecking process. It is known that the chests would be normally stored in the safety of the captain's cabin. Therefore, the systematic positioning of artefacts recovered, combined with the knowledge the standardised stored of VOC wreck, is critical to understand what happened to the artefacts during the post-wrecking process.

6.6.3.2 Spatial Distribution of Artefacts on the Rooswijk on the West site (Main site)

The general distribution of artefacts on the west site (main site), delineates an elongated shape with a northwesterly-southeasterly orientation (Figure 93 (A)). Visibly, there is a larger concentration of artefacts to the northern part of the site, but there is an even distribution of smaller artefacts following the heavier and larger features (stone block, anchors, copper sheets, guns and loose timbers).

The tools, equipment and ship fittings are scattered around the site, with a slightly higher concentration to the northern part of the site (Figure 93 (B)).

The specie is clearly concentrated on the northern section of the site, showing several clusters, that is most likely a consequence of the storage within the shipboard associations (Figure 93 (C)), Figure 94, Figure 95 and Figure 96). The clothing and domestic artefacts have a general distribution with very few elements to the south of the site (Figure 93 (D)). Cargo artefacts are mostly concentrated in the central part of the site, while domestic artefacts are more widely spread (Figure 93 (E)). The ordnance artefacts are concentrated in the northern part of the site (Figure 92 and Figure 93 (F)). The guns show a degree of alignment in a northwesterly-southeasterly direction, possibly showing the way the gun-deck collapsed (Figure 93 (F)).

The amount of specie concentrated in the northern section required a closer look by dividing it into the different types. As explained in the previous section, the specie was stored on board in a systematic and orderly fashion. Considering that there would be 4000 ducatons per chest, it is almost certain that we are not dealing with the contents of a complete box. During the excavation, parts of what seemed to be a box where found, but the wood was extremely damaged by erosion. This would indicate two things: that this section was exposed to and eaten by gribble (*Teredo navalis*), as well as physical erosion had led to these boxes being broken up. Some of the coins were concreted together in stacks, showing how they were stored in a container or box (Fig. Figure 95 (B)).

The total of Dutch specie was 652 (48. 43 %) compared to 694 (51.56 %) of Spanish specie (Figure 91). However, their distribution around the wreck differs substantially. The Spanish specie was found widely spread in the northern section of the wreck. While the pillar dollars were found mostly in two main clusters and the rest, scattered mainly around the northern part of the site (Figure 94 (B)). The cobs were also spread around the northern part of the West site, and more abundant than the pillar dollars. They were the most abundant type of specie found on the wreck and mostly concentrated into two large clusters (Figure 94 (C)). The Dutch specie was found concentrated in small areas, found close to the Spanish specie clusters (Figure 94). The ducatons were found in two clusters, and a few scattered to the east of the site (Figure

94 (D). Most of the rijders, 283 out of 293 (96.59 %) were found in a reduced area indicating that they were stored in the same bag, box or broken chest (Figure 94 (E)). The stuviers were found in the same northern area of the site the ducaton but spread out in a larger space. Only a few were found scattered around the site to the east of the clusters (Figure 94 (F)).

The analysis of artefact distribution across the west site identified a clear relationship between the artefact class' location and their shipboard association. Considering that the standard VOC ship measured 145f t (47.39 m) in length (Bentam 1742b), the main site presents the length of the missing wreck structure. Based on *in-situ* observations, the MBES time-series, and the USBL artefact distribution patterns, it seems that the stern was located where the highest concentration of specie was found (Figure 97). The elongated pattern of artefacts indicates a possible orientation of the *Rooswijk's* deposition on the seabed when it still had an extensive coherent structure.

The meticulous recording of artefacts during the excavation has revealed that the *Rooswijk* is a scattered wreck site with an order or pattern of distribution that was previously unknown.

Figure 92. The image shows a diver recovering a Breech Block. The picture is courtesy of Michael Pitts kindly provided by the Rooswijk Project 1740. The author of this thesis processed the picture.

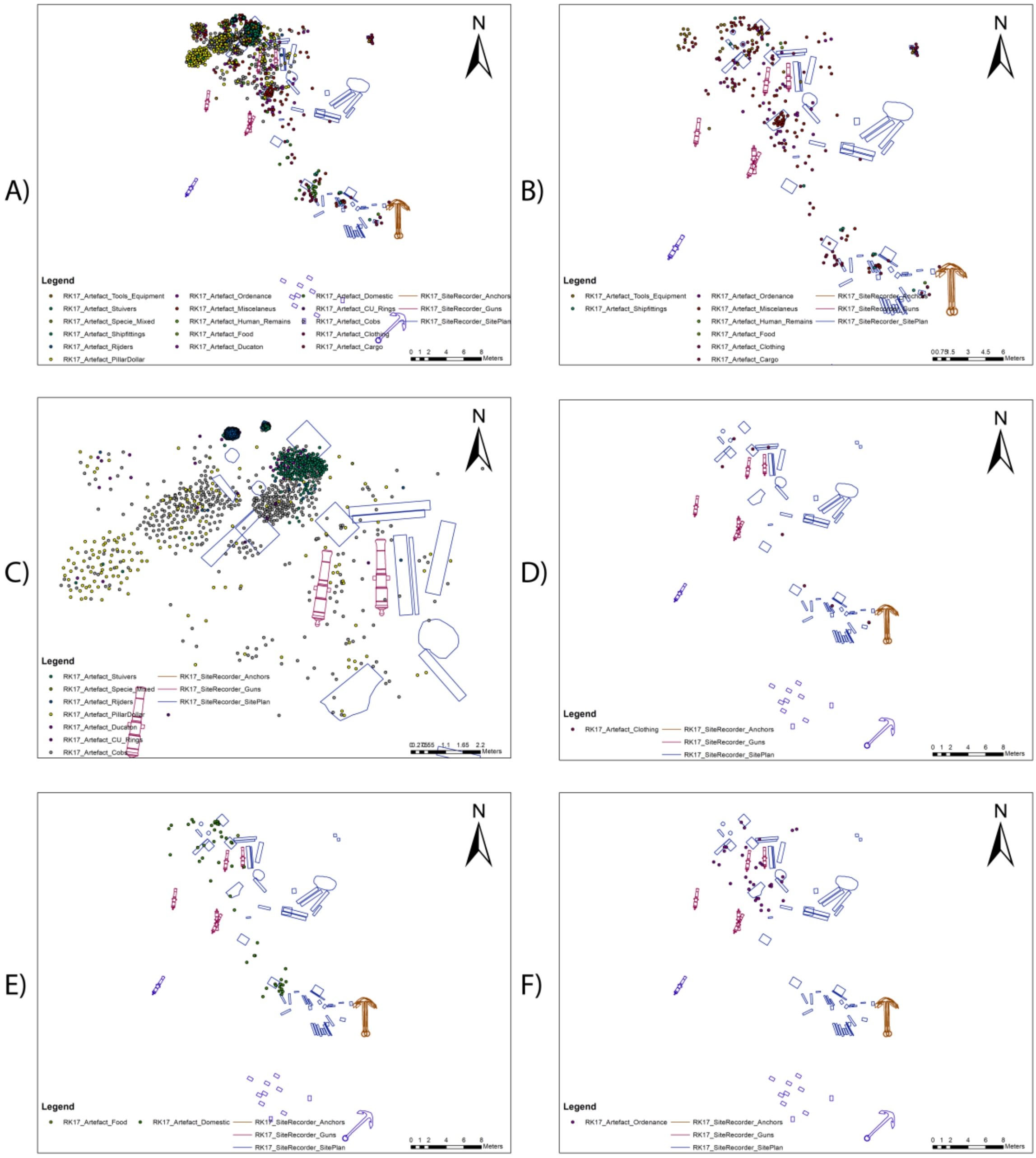

Figure 93. The maps show artefact distribution of specie on the *Rooswijk* with a site plan. A) Artefact distribution, B) Tools-equipment and ship fittings, C) Specie distribution D) Domestic and Clothing distribution, E) Cargo and domestic distribution, F) Ordnance distribution. The maps of artefact distribution where made with Site Recorder 4® and converted into Arc Map 10.5®. The author of this thesis created the figure. (Full-size images are found in Appendix II, B. *Rooswijk*).

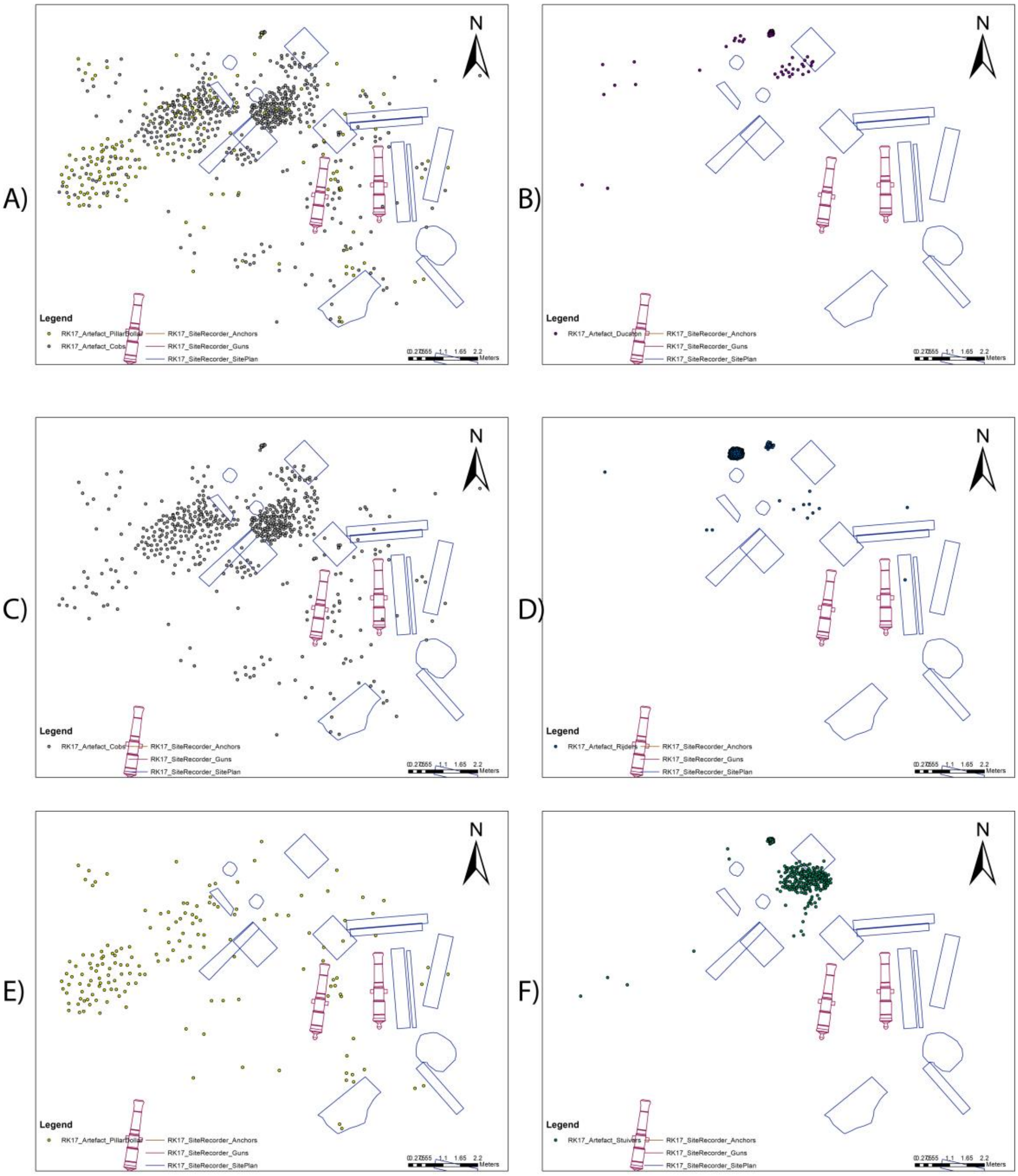

Figure 94. The maps show the specie distribution on the *Rooswijk* with a site plan. A) All the specie, B) Ducaton C) Cobs D) Rijders, E) Pillar Dollars F) Stuiver, The maps of specie distribution where made with Site Recorder 4® and converted into Arc Map 10.5®. The author of this thesis created the figure. (Full-size images are found in Appendix II, B. *Rooswijk*).

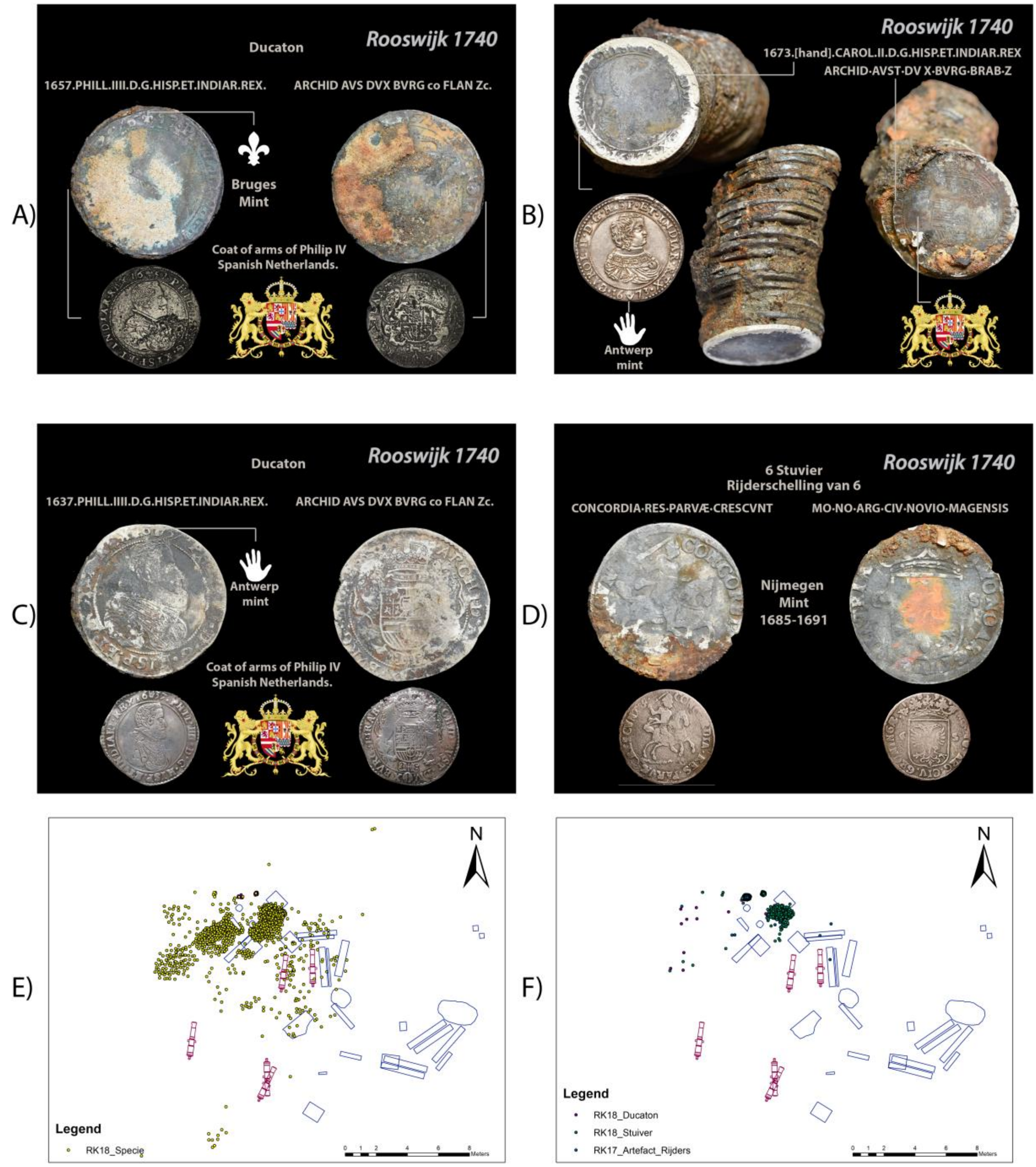

Figure 95. The figure shows Dutch specie distribution found on the *Rooswijk* A) Phillip IV Ducaton, Bruges Mint, B) Charles II Ducaton, Antwerp Mint, C) Phillip IV Ducaton Antwerp Mint, D) 6 Stuiver, Nijmegen Mint, E) Specie distribution in the West Site (Main Site), and F) Dutch specie distribution in the West site (Main site). The maps of coin distribution where made with Site Recorder 4® and converted into Arc Map 10.5®. The author of this thesis created the figure.

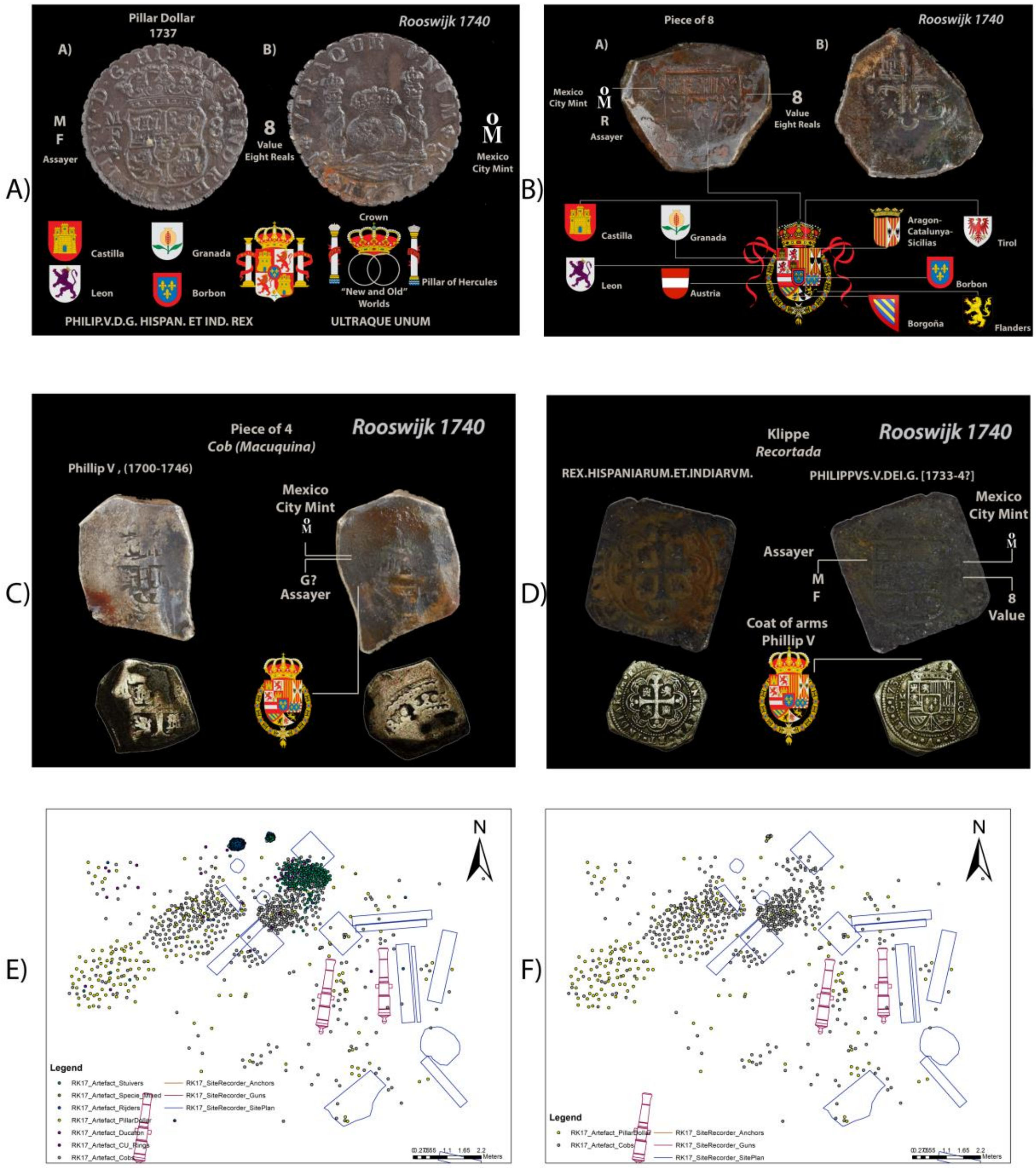

Figure 96. The figure shows Spanish coins found on the Rooswijk and the distribution maps. A) Phillip V Pillar Dollar, Mexico City Mint, B) Phillip V cob piece of eight, Mexico City Mint, C) Phillip V cob piece of four, Mexico City Mint, D) Phillip V Klippe pierce of eight, Mexico City Mint E) Specie distribution in the West Site (Main Site), and F) Spanish specie distribution in the West site (Main site). The maps of coin distribution where made with Site Recorder 4® and converted into Arc Map 10.5®. The author of this thesis created the figure.

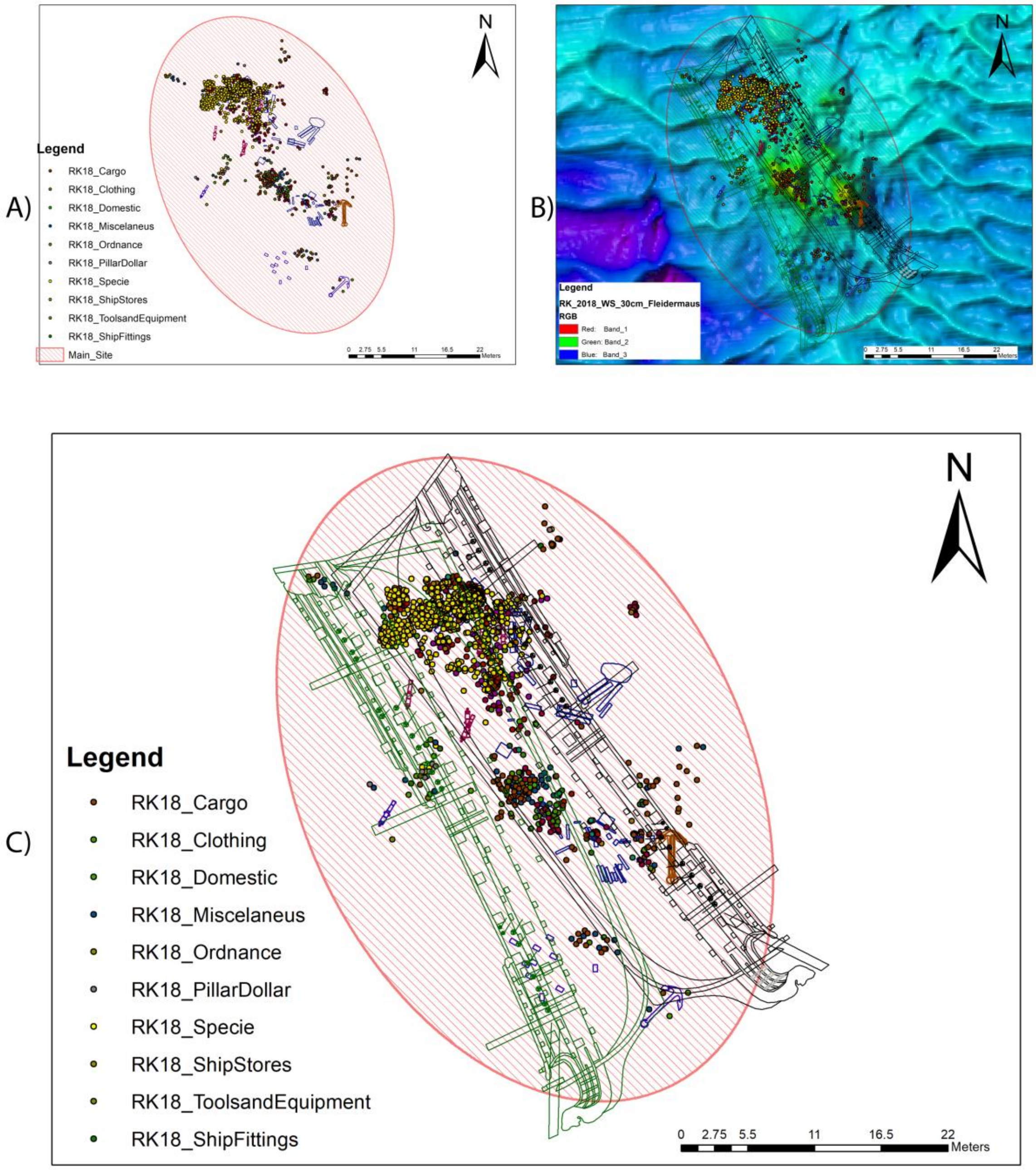

Figure 97. The figure shows the artefact distribution in the West site (Main site). A) General artefact distribution, B) General artefact distribution overlaying the MBES survey from 2018. C) A site interpretation based on the artefact distribution. The author of this thesis created the figure.

6.7 Discussion

On a macro-scale, the *Rooswijk is* located in a moderate-energy environment (M2aM[361]), with no extant structure and many artefacts scattered in order. However, more detailed studies with high-resolution MBES survey, and *in situ* observations reveal a more dynamic environment. This is possible due to the resolution of the bathymetry used by EMODnet (EMODnet 2018). As discussed in this chapter, the Goodwin Sands presents a challenge to model. Considering that the Kellet Gut indicates that it was formed by the separation of the South Calliper and Goodwin Knoll (Astley 2016:166; Eldersfield 2001), this indicates that large sand dunes have moved across the site since its wrecking. Additionally, the three-year (2015-2018) survey period observed on the MBES time-laps has demonstrated that on a mesoscale this environment is very dynamic. The mesoscale MBES timelapse indicate that there are two main types of sediment migration patterns on the *Rooswijk*: the medium size sand banks that are migrating to the south as they follow the migration of the South Calliper and the smaller sand ripples that follow the tidal regime with major changes between spring and neap tides. The localised seabed migration observed with the UHR MBES system would have changed dramatically along with the larger sandbank dynamics throughout the period of 250 years since the wrecking, the exact seabed movement patterns are difficult to reconstruct from the wrecking event to present. However, the scattered distribution of sites (west, east, north and northeast), suggest that the wrecking event split the ships' structure into several parts. Observations show that several wrecks in the Goodwin Sand (e.g. *Stirling Castle*, *Restoration,* and *Admiral* Gardner) and the Downs (GAD 23, "Bowsprit wreck"[362]) with an extensive structure have collapsed due to a combination of loss of sediment caused by scouring and the weight the sand within the wreck that causes the hull to bulge and eventually crumple (PAS 2017). It is likely that if any of the *Rooswijk's* structure survived the wrecking process, it would have also suffered a similar process of disarticulation.

The seabed migration pattern subject to tidal movements across the west, east, north and northeast sites of the *Rooswijk,* represent the major *scrambling factors* and *extracting filters* for the artefacts. Nonetheless, the intra-site scale analysis with

[361] See Table 21 in section 4.3
[362] GAD 23 is also known as the Bowsprit Wreck due to the fact that when it was first surveyed it was very intact, still with its bowsprit attached (Pascoe 2017: 15).

artefact distribution analysis demonstrated that despite the dynamic environment, it is possible to deduct the relationship between artefacts and their shipboard associations (Figure 97). Furthermore, it is difficult to distinguish between smuggled and official VOC money based only the spatial distribution of specie of the *Rooswijk*.

6.8 Conclusions

The critical multiple-scale analysis presented above concludes that the site could be better classified as a high-energy environment, presenting scattered ordered distribution of many artefacts (H3bM) [363], with the extreme mobility of sand due to the tidal-energy.

There are 53 Protected Wreck sites in British waters, of which 19 have extensive structural remains, 16 only with elements and 18 with no structure. Of those 53 Protected Wrecks, 22 have a coherent spatial distribution, seven are scattered ordered, and 24 are scattered disordered [364]. Before this study and the excavation of the *Rooswijk*, the site was catalogued as scattered disordered. However, based on the spatial distribution of artefacts we can confidently say that there is still correlation were the ship structure laid on the seabed. As Martin pointed out, the more dynamic and destructive the wreck formation processes, the greater will be the demands on archaeologists who seek to record and understand them (Martin 2005:208) and the *Rooswijk* is no exception.

This thesis aims to provide better archaeological interpretations based on integrated methodologies. The Integration of historical, environmental, remote sensing and *in situ* observation was essential to understand the site formation process of the *Rooswijk.* The environmental dynamics and the overall special distribution of four scattered sites (west, east, north and northeast) were mapped out with a site-tailored UHR MBES time-lapse. The USBL system was crucial for mapping out the artefact distribution and georeferencing the MIP survey of the main site.

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[363] Full classification in Table 16, section 4.4.
[364] See Chapter IV and Appendix I

The combination of pre-disturbance, post-disturbance surveys and *in situ* observations allowed a possible wrecking process trajectory to be reverse-engineered. After carefully analysing the available datasets, the interpretation of the wrecking processes concludes that the Northeast site has 10 guns in a line across 35 m that would fit 47 m length of the vessel. These guns present an orientation that suggests they were jettisoned from a ship on both port and starboard sides. For this, the Northeast site seems to be where the *Rooswijk* ran aground on a large sand dune, and the crew managed to get off by lightening the ship. The *Rooswijk* possibly suffered severe damages to the hull and that caused her to spill granite building blocks, located in the stores, on the east Site. It is also possible that she struck another sandbank, causing further damage to the structure. In the desperation of trying to save the ship, the crew jettisoned barrels that now lie on the north site. The *Rooswijk* must have been severely damaged and taking in water when she finally sank in a south-westerly direction, creating the mound in the main site (west site). The post-depositional process disarticulated the remaining structure of the ship and scattered the artefacts across the seabed.

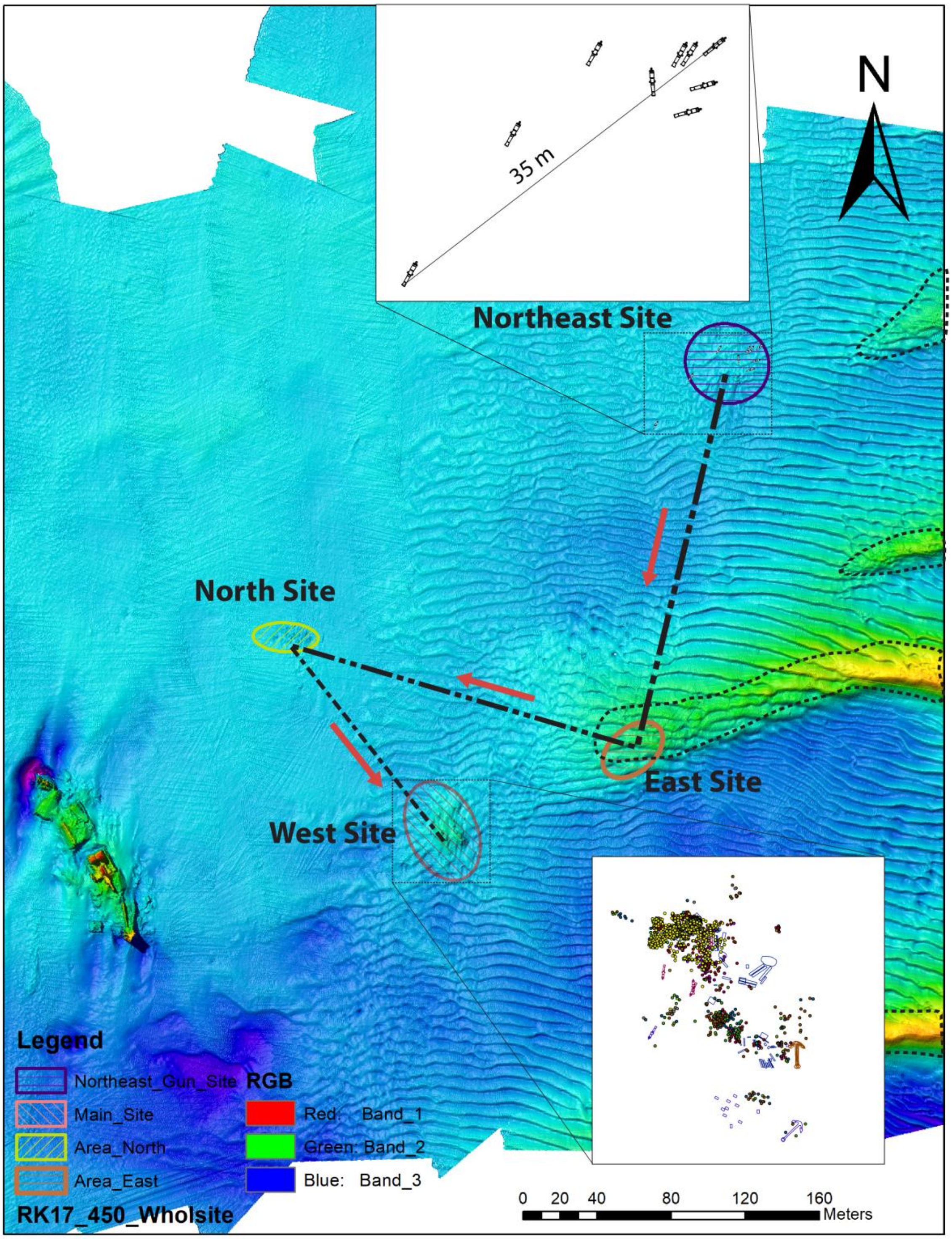

Figure 98. The figure shows the possible impact site (Northeast site) and the potential wrecking trial based on the debris. The data was kindly provided by PAS, commissioned by HE to manage the Goodwin Sands and Downs MB Survey (PAS 2017). A collaborative team including Pascoe Archaeology, MSDS Marine Ltd and Swathe Services carried out the survey. The artefact positions were kindly provided by the Rooswijk 1740 Project. The author of this thesis created the map in ArcMap 10.5 ®.

6.8.1 Best Practice and Recommendations for Further Research

The Rooswijk 1740 Project has made progress in understanding the sites' environmental dynamics, the wrecking process and the artefact distribution on multiple scales. Yet the wreck still has tremendous potential for future research. So far, no coherent structure has been found, only disarticulated structural features.
The close examination of the *Rooswijk* shows how the site is vulnerable to a high energy environment (HE 2018c). The vulnerability of the UCH of the *Rooswijk* should be emphasised within the criteria of Protected Wrecks at Risk (HE 2017a, 2017b) by expanding the definition of environmental energy[365]. Additionally, the extent of the remains of the *Rooswijk* goes beyond the designated area of protection afforded under the Wrecks Act of 1973 (Crown 1973). Therefore, it would be wise to extend the Protected Wreck designated area by HE to include the northeast site, which is the potential impact site.

To understand the impact of the environment on site continued monitoring of the *Rooswijk* on an annual basis using the same high-resolution MBES systems, has been demonstrated to be highly effective, offering a better mesoscale understanding of the site dynamics with the mobile subaqueous sand dunes and identifying the direct impact on the site. This should be integrated to further multi-image photogrammetric surveys of the main site (west Site), and other features if the site conditions allow it. The use of a USBL system or a similar live tracking and posting system for any future excavations on the site should be used as it has been demonstrated to be an ideal recording tool for understanding the artefact distribution and its shipboard associations.

Lastly, the Goodwin Sands is a truly remarkable part of the world that holds underwater cultural heritage with enormous historical importance not only for the UK but for global history. As demonstrated in this chapter, further archaeological research on the *Rooswijk* and other wrecks in the Goodwin Sands should be encouraged using integrated methodologies that are able to describe multiple levels (macro, meso and intra-site). Encouraging site-tailored methodologies to produce better archaeological

[365] See sections, 4.1.5 for energy, 4.2.4 for protected wrecks at risk and 4.3 for shipwreck classification based on the environment.

interpretations that will lead to better strategies of cultural heritage care as demonstrated in this chapter.

Chapter VII. HMS *Invincible* 1744-1758 in the Eastern Solent

The aim of this chapter is to demonstrate the full potential of integrating remote sensing on multiple-scales, with intra-site analysis and *in situ* observations. The results presented from the Multi-beam Eco Sound (MBES) and Multi-Image Photogrammetry (MIP) time-series were essential to re-interpret previous archaeological work adding to our understanding of site dynamics and extant features of the ship itself. This integrated methodological approach addresses the need to integrate MIP with other survey techniques for further analysis, as MIP provides both valuable qualitative and quantitative data, to better understand site formation processes.

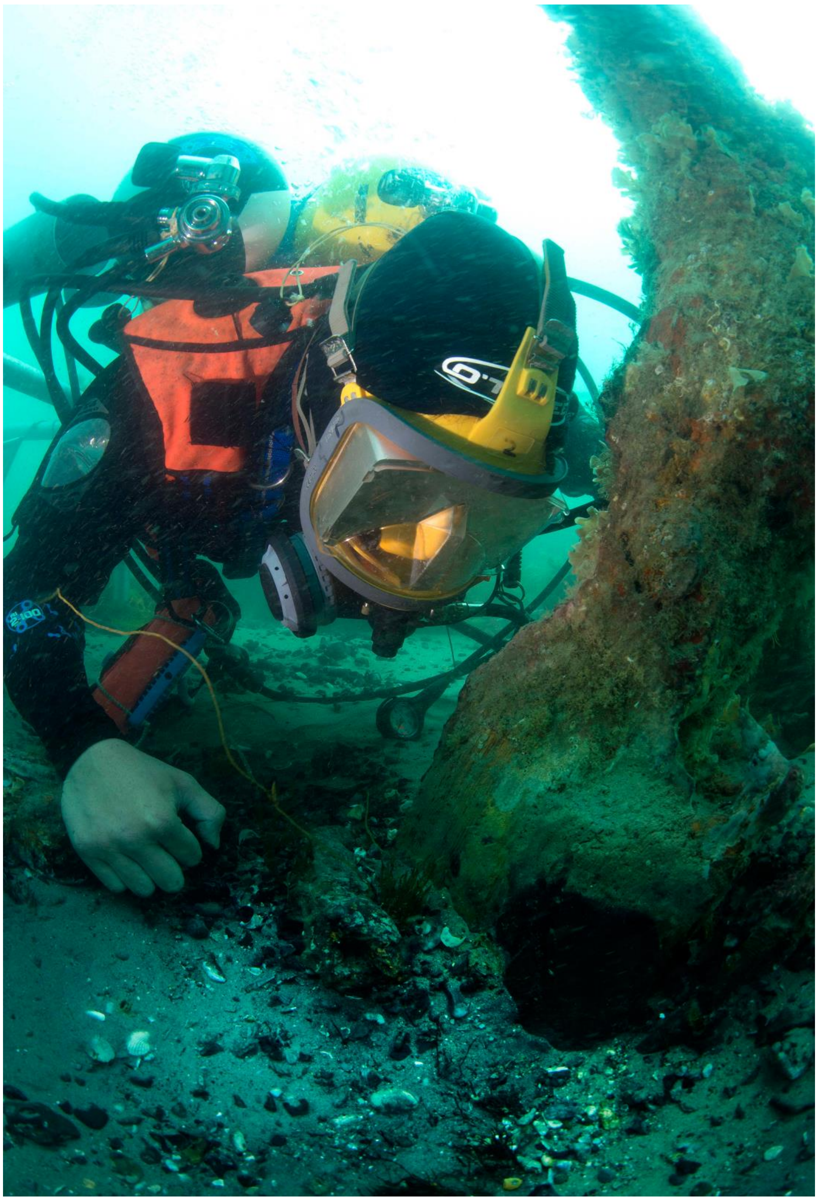

Figure 99. The image shows an iron knee, supporting the gun deck in Area 1, exposed in 2017. Image courtesy of Michael Pitts. The image was kindly provided by BU and the Invincible 1744 Project. The author of this thesis modified and adjusted the picture.

7.1 Historical Background

7.1.1 Ship Construction

L'Invincible was launched into the River Charente in Rochfort, France, on 21st October 1744. She was the second of an entirely new generation of 74-gunships, that would dominate the sea for the next 50 years.

The first was *Le Terrible*, designed by shipwright master François Coulomb in 1739 at Brest. He lengthened the hull, which allowed for the fitting of extra gun ports on each side of the upper and lower gun decks. This meant that the guns did not have to be carried on the poop deck. Instead, a higher number were carried on the lower decks, thus increasing the firepower of the ship and lowering the ship's centre of gravity, increasing stability (Lavery 1988:3; Pascoe 2013:2).

In 1741, the minister of *La Marine* commissioned the *Invincible's* construction to Pierre Monrineu. He was to work in the same shipyard, beside Geslain, who was looking after the construction of another 74-gun ship, *Le Magnanime* (Figure 100 and Figure 101). Their experimental design would make them faster and more manoeuvrable than previous 74-gunships.

The *Invincible* is not only significant because of her revolutionary design but also because of the new technologies used in her construction. For example, timber shortages led to the development and use of iron knees in the construction of her hull (Lavery 1988:9; Pascoe 2013:2). Although, on Invincible, these knees were used to hold the gun-deck, presumably because of their weight carrying capacity, they were also covered by pinewood cladding. The aesthetic of an iron knee was not something typically accepted in ship design at the time. This is most likely because using iron in this way was not typical in ship design and, as a result, was not seen as aesthetically pleasing. Covering them in pine would, therefore, give the appearance that the ship was, in all of its elements, still recognisable as a ship.

Invincible was equipped with 74 guns, distributed around the ship. On the Main-Deck were twenty-eight 32-pdrs, the Upper-Deck thirty 18-pdrs (replaced by thirty 24-pdrs of the new lightweight design) and the Quarterdeck sixteen 9-pdrs (Figure 102 and Figure 103).

The overall dimensions of *Invincible* were: length of Gun-deck: 171ft 3in[366] (52.2 m), length on keel for tonnage: 143 ft 6 in (43.7 m), breadth (extreme): 48 ft 11 in (14.9 m), and depth in hold: 21 ft 3 in (6.5 m) (Bingeman 2010; Government of Canada 2018).

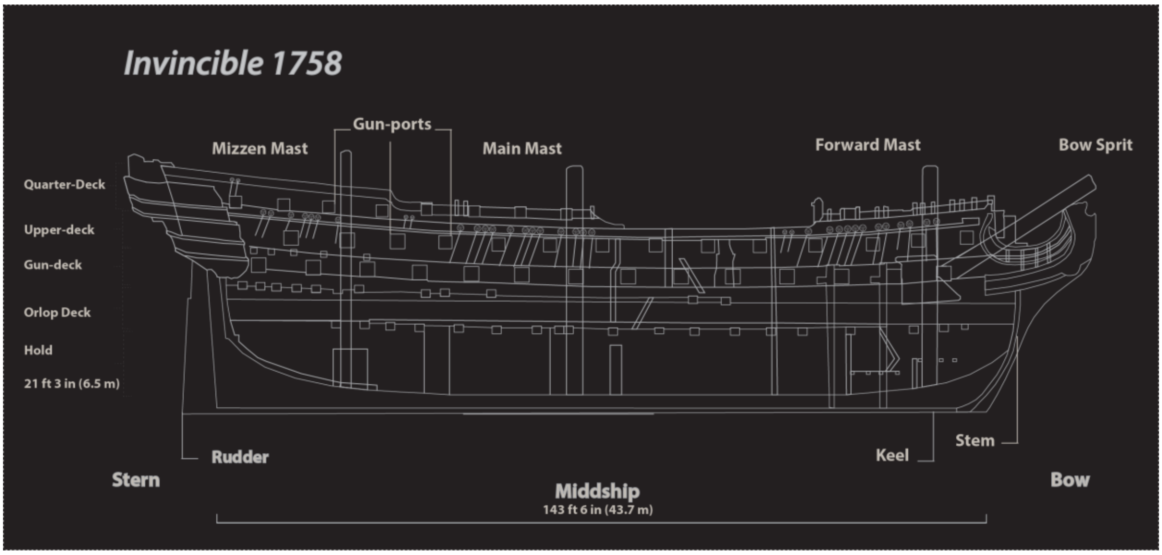

Figure 100. The lines plan is based on another 74 gunship, *Le Magnanime*, that was also built in Rochefort at the same time as *Invincible*. The lines plan was drawn by the author based on a survey done on *Magnanime* after being captured in 1758, held at the NMM (Unkown 1758)**. The author of this thesis created the figure.**

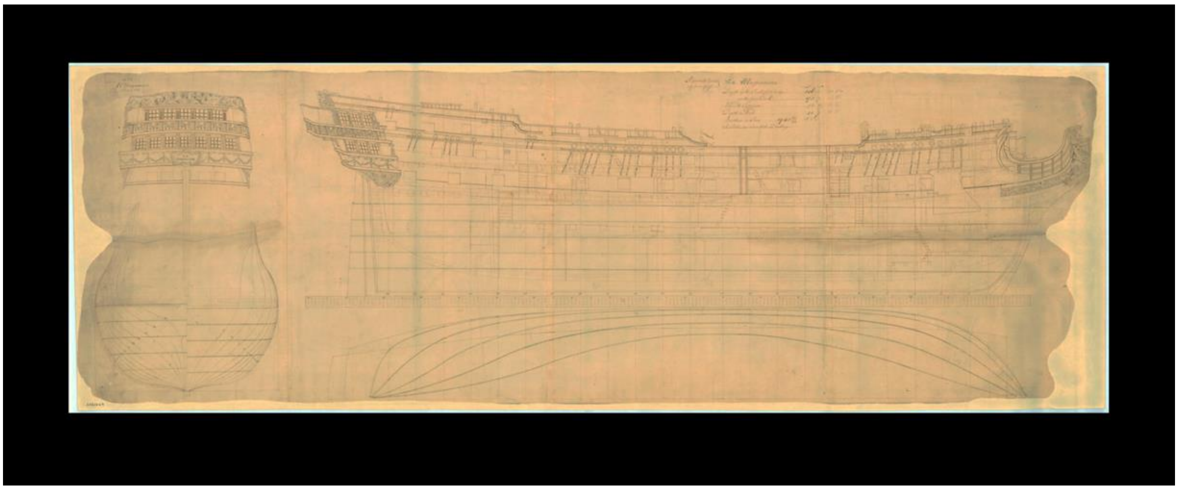

Figure 101. *Le Magnanime* captured in 1758. Ship plan was drawn in Plymouth after capture and taken for repair, currently held at the NMM in Greenwich, London (Unkown 1758)**. The author of this thesis created the figure.**

366 1 *Pied* or French foot = 12.789 inches. Assuming 25.4 millimetres per inch as per international agreement. 1 foot (French measure) = 0.3248406 m. (Government of Canada 2018).

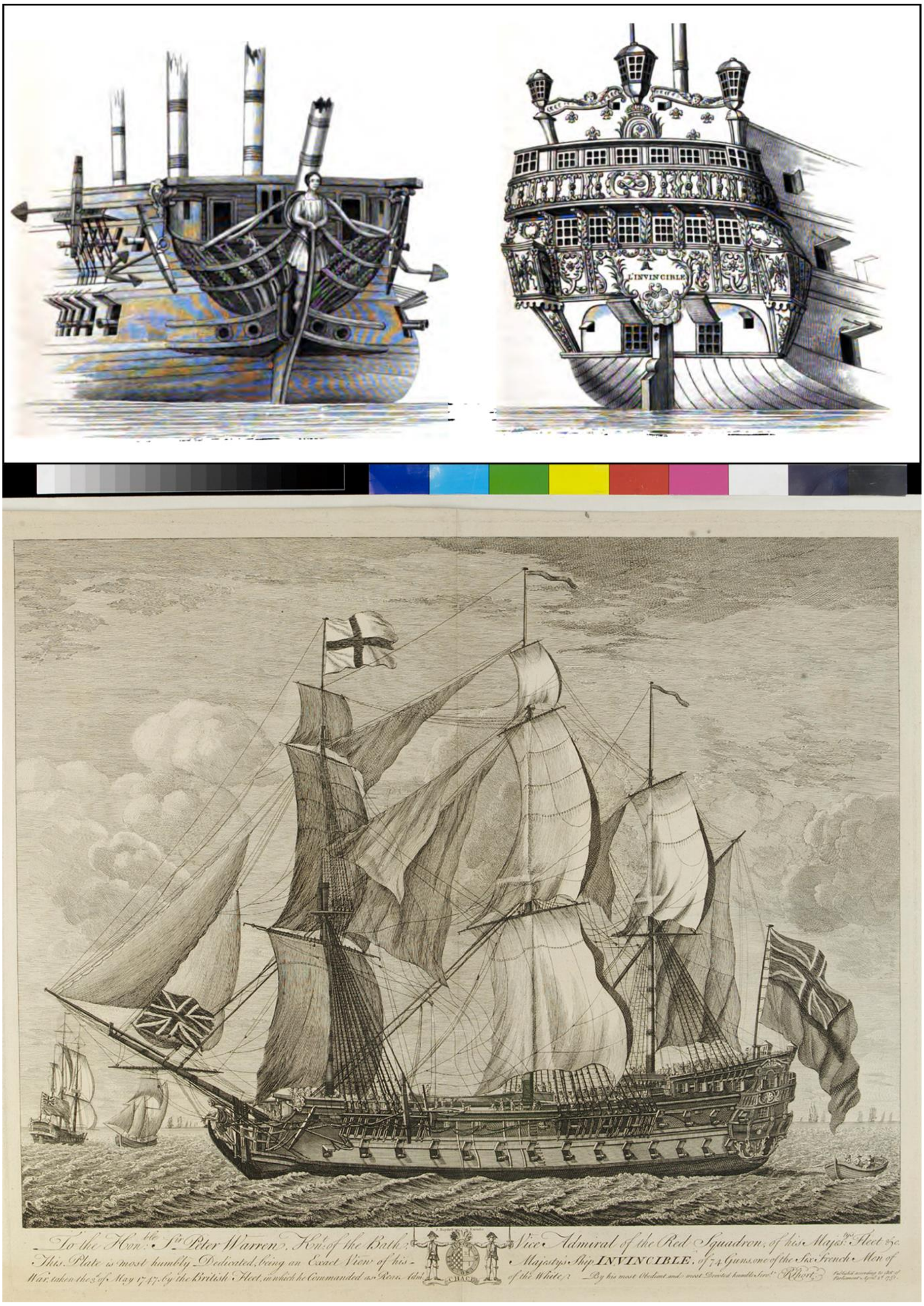

Figure 102. NMM. Top illustrations show details and decorations on bow and stern (Fincham 1851:84–85)**. While the illustration on the bottom shows HMS *Invincible* with full rigging** (Mynd, Boydell, and Short 1747)**. The author of this thesis created the figure.**

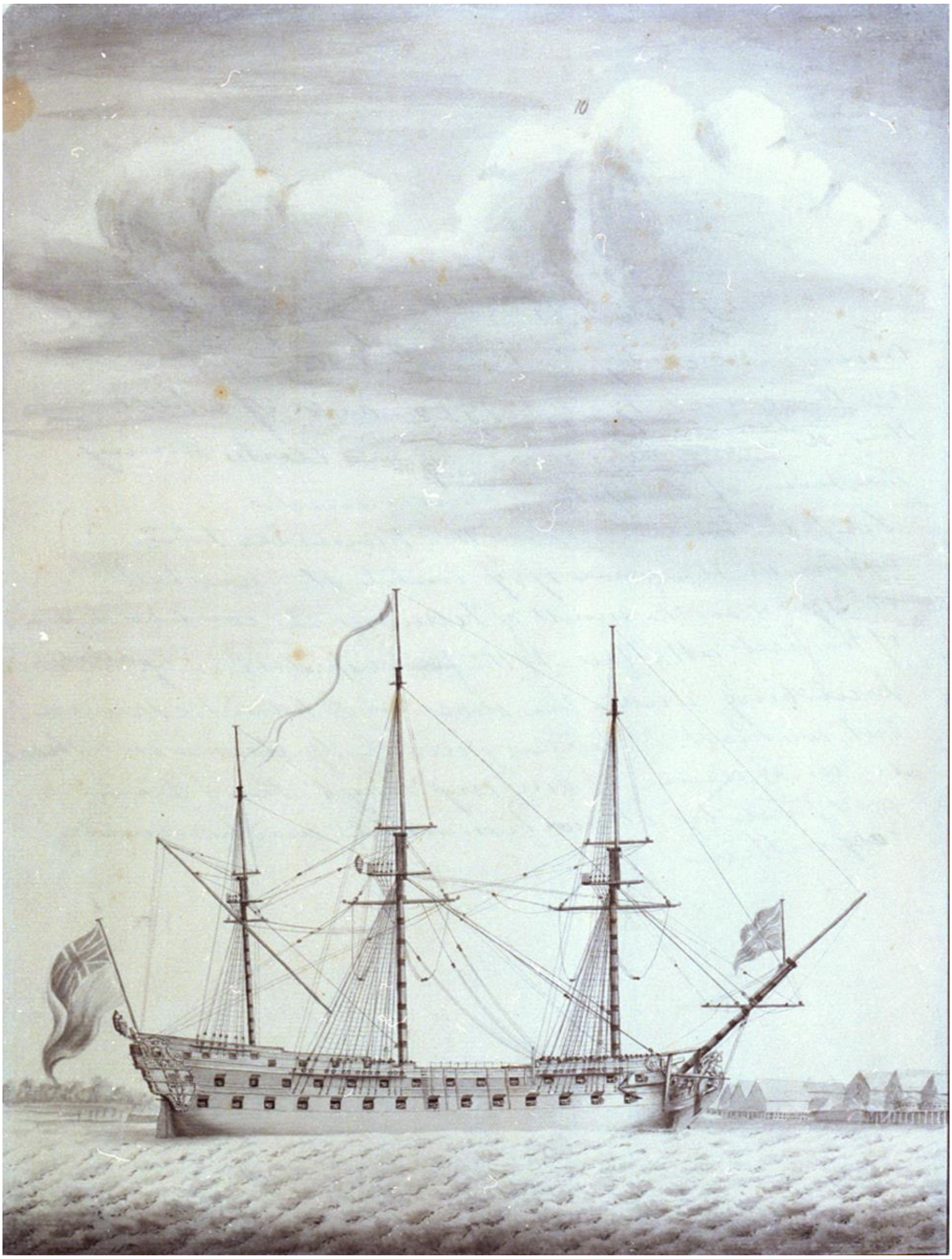

Figure 103. Invincible by John Hood NNM, Greenwich, London (Hood n.d.)**. The author of this thesis enhanced the image.**

7.1.2 Service in *La Marine* (French Navy)

L'Invincible had a short but successful service in the French Navy (Bingeman 2010:5–6). She performed her duties alongside *Le Magninime* (Figure 101) escorting an annual convoy of merchant fleets that were importing sugar from the West Indies. Narrowly escaping from a superior English force *Stratford* 50-gun, *Plymouth* 60-gun and *Lyme* 24, between Dominque and Cuba in 1745.
However, on 3rd May 1747, she was not so lucky while sailing to escort a *Compagnie française pour le commerce des Indes Orientales* (French East India Company) convoy, headed for Lorient. She unexpectedly ran into a fleet commanded by Admiral Lord Anson and was captured near Cape Finisterre, Spain. She was then towed back to Portsmouth where she was purchased, extensively repaired and recommissioned for the Royal Navy (RN) (Bingeman 2010:7; Lavery 1988:24).

A few months later *Le Magnanime* was also captured by the Edward Hawke, and taken to Plymouth where she was surveyed (Colldege and Warlow 2010:243; Hawke 1990:41–42). Although *Invincible* had no plans made of her, the survey of *Le Magnanime* provides plans from when she was captured. These were archived at the NNM (Figure 101) and they could aid our interpretation of how the wreck lies on the seabed (Unkown 1758). Other ships based on the lines of *Invincible* can also be comparative examples: the *Ajax* (1798) and the *Kent* (1798) (Lavery 1988:38, 94; Unkown 1798)(Lavery 1988:38,94).

7.1.3 Service in the Royal Navy

The ship was purchased from the French Navy and renamed as the HMS [367] *Invincible*[368]. Admiral Lord Anson had noticed the vessels' fine lines and particular design while heading back to Portsmouth, and immediately sent a ships' carpenter to take measurements (Bingeman 2010:7). Lord Anson, Benjamin Slade[369], and John Goodwin were to be the driving force to incorporate *Invincible's* superior build and sailing qualities in the future designs of the Royal Navy. The capture of ship "prizes" began to show significant influence upon shipbuilding technologies in the eighteenth

[367] His or Her Majesties Ship. In this case, it is His Majesties (King George II 1727–1760).
[368] A fee was payed for keeping a captured enemy vessel, established in a Prize Law.
[369] Shipwright master at Plymouth (from 1746 to 1750).

century across Europe, between the main maritime powers (Adams 2013a:10; Holland 2015; Mckee 1972:234). The *Invincible* was part of this process with Sir Thomas Slade, the designer of Nelson's Victory, later developing the *Dublin class* based on the lines of Invincible (HWTMA 2010:8). At the time of the Battle of Trafalgar in 1805, the majority of the British fleet was composed of these 74-gunners.

During her service in the Royal Navy, she underwent major repairs between 1753 and 1756 (Pascoe 2013:5). Some patches and possible repairs have been identified on the wreck. However, a more detailed intra-site analysis is still required to answer specific questions of size and dimensions of timbers, as well as their fastenings, some of which have been documented by Bingeman (Appendix A 2010).

7.1.4 The Wrecking

'*Invincible is got on Shore on the Dean Sand, and is a Ground. I have sent met the Masters attendant Shipwrights and a Pilot, with an Anchor Cable and all the Dock Vessels to her Assistance to and come over to get her off*' (NMM, R. Hughes 19th February 1758 POR/D13)

The wrecking process is thoroughly described in Capitan Bentley's log (PRO Adm 51/471 1758), Lieutenant's Logs (ADM/L/J/ 87 1758), the court-martial minutes (PRO. ADM 1/5297 1758) and the POR[370] series. Their interpretation, as well as partial transcription, can be found in Lavery (Lavery 1988:97–105) and Ortiz-Vazquez (Ortiz-Vázquez 2013:9–16).

On 19th February 1758, a fleet under Admiral Boscawen's command would set sail from Portsmouth bound for Nova Scotia on a second attempt to take the French fort of Louisbourg. *Invincible* was meant to take part in this expedition but after a series of calamitous of events, she could not leave the Solent. She was moored at Spithead on the 31st January, twenty days before, waiting for orders. Captain John Bentley received orders *at ½ past 2 am* [when] *Admiral Boscawen made the Signal to weigh* (PRO ADM 1/5297 1758a). Unfortunately, her anchor stuck fast in the mud impeding any movement despite the 384 men powering both of her capstans. The rest of the fleet

[370] POR, Portsmouth Dockyard: Navy Board Orders (originals), to respective Officers (ADM/Y/5 1758; ADM 106/1191 1758; ADM 2/522 1758; ADM 51/673 1758; POR/F/11 1758; POR /D/13 1758).

decided to continue, leaving *Invincible* behind. [...] *at ¼ after four we weighed: when the Anchor was near up we found the stock to be foul to the mast* (PRO ADM 1/5297 1758a). The pilot noticed that tiller ropes were fouled in the gunroom. He immediately ran aft to the wheel and ordered two-quarter masters to assist in getting the helm up, but they were unsuccessful. *Invincible* was being pushed by an ESE wind when she ran aground on the SE Part of the Dean (PRO ADM 1/5297 1758b). After several attempts at getting her off, they only managed to move the ship slightly. After two days of effort, the men were exhausted and the weather had worsened, when they started to take on water and the pumps failed. Finally, the inevitable happened, and she capsized (Lavery 1988:97). With water up to the orlop deck, the stores on the bottom of the hull were entirely flooded and inaccessible.

7.1.5 The Salvage

As the majority of the upper structure of *Invincible* was still above the waterline, the ship was salvaged over a period of seven months. They managed to retrieve all of the guns, masts, bowsprit, rigging and some of the stores. However, the weight of the ship caused the wreck to sink progressively more into the sand, making it impossible for the salvage efforts to reach the lower parts of the ship, with the bow almost fully immersed (Lavery 1988:102).

On May 8th of the same year, a survey conducted by Portsmouth officers reported that *Invincible* was lying on her port side at an angle of about 30º degrees, with almost all of her gun-deck underwater. The water had '*a clear passage through her*'. She was '*greatly twisted, waving and cambered*' (Lavery 1988:104).
As she sank even further into Dean Sand and gradually lost even more of her upper structure, salvage operations were entirely abandoned. As the sands swallowed her, *Invincible* was eventually forgotten for the next 250 years.

7.2 Previous Work on Site

On the 5th May 1979, Arthur Mack, a local fisherman, went out trawling around Horse Tail Sand when his net snagged. When Mack attempted to retrieve his net, he also pulled out a square piece of timber with treenails. That same afternoon, he went back to the site with two diver friends, John Broomhead and Jim Boyle. They collected several artefacts, took pictures of what they had found and later reported them to the Royal Navy Museum (RNM). The RNM put Mack in contact with Jon Bingeman, who at the time was responsible for digging the *Needles wreck* (HMS *Assurance 1753*) and the *Pomone* (1811) (Satchell and Whitewright 2014). Bingeman immediately recognised the potential of this wreck. On the 30th of September 1980, the site was protected under the PWA (Crown 1973), before the site had been formally identified. For a more extensive account of the development of this project see Bingeman (2010) and for an updated summary see Table 28.

In 2013, Dan Pascoe took over the responsibility of becoming the licensee of the site, picking up where Bingeman had left off. The *Invincible* was progressively deteriorating as sand migrated off the site leaving timbers and loose artefacts at the mercy of the sea. With this, a thorough assessment took place to both record the remaining structure and evaluate its vulnerability. As became evident, the wreck was under threat of becoming ever-more exposed as the Horse Tail Sand gradually migrated south (Ortiz-Vázquez 2013; PAS 2015). This motivated efforts to record using extensive pre-disturbance surveys at a high resolution. With new partnerships and funding, it was possible to continue with an excavation on site, allowing for better understanding of the ships' structure and site formation processes through the new data and the reinterpretation of past work (Table 28).

Year	**Chronology of research carried out on HMS *Invincible***
1980	The first attempts to recognise and map the site were carried out by a small team of divers.
1981	A series of trenches were made from 'A' to 'D', which were partially re-opened in 1983 and 1984. The identification of the *Invincible* was corroborated: while excavating the Forward Sail Room, Bingeman found within a folded sail a tally stick with the name of the ship (Bingeman 2010:25).

1982	No excavations took place, as C. Bingeman was involved in the Falkland (*Islas Malvinas*) War administration.
1983	Trenches 'A' to 'D' were re-opened and fully excavated, exposing a large area of the port side.
1984	A second survey, using Direct Survey Method (DSM), was carried out by Ian Oxley, Alex Hildred, Barrie Adrien and John Bingeman.
1985	Repeat pre-disturbance survey and a small exploratory trench were made in the stern area. The hull orientation was determined as well as the stern and bow sections.
1986	A full excavation was carried out on two trenches (10m x 5m), labelled 'North 86 and South 86'.
1987	A full excavation was carried out on four trenches (5m x 5m), labelled '87'. These were split into 'NW, NE, SE and SW' (Figure 104).
1988	A full excavation was carried out with six trenches (5m x 5m), labelled '88A to 88F'. Trench 'Δ88', previously opened in 1981, was re-opened to complete excavation. 'The Royal Navy's First Invincible 1744-1758 The Ship, the wreck and the recovery' by Brian Lavery was published (Lavery 1988).
1989	An extensive excavation was carried out with twenty trenches (5m x 5m), labelled 'G to Z'. Trenches 'P, R, Y and Z' were not entirely clear due to collapsed heavy timbers
1990	Seven slightly lager trenches were excavated, labelled 'AA, BB to JJ'.
1995	A geophysical survey was done with Side Scan Sonar by the NOC-University of Southampton.
1997	NOC-University of Southampton repeated the survey after significant damage was done

	to the site by a merchant's vessel MV AMER VED that ran aground on the site (Bingeman 2010:61; Quinn et al. 1998:134). The stern section was heavily damaged. The sternpost was broken off, three iron knees and many frame timbers were severely ruptured.
1998	A geophysical assessment based on 3D Chirp Sub-bottom profiling and SSS was carried out by the University of Southampton (Quinn et al. 1998) Also, Bingeman presented a complete composite plan showing previous work, and presenting a coherent port side structure.
2001	The Archaeological Diving Unit (ADU) did a Side Scan Sonar survey (no data available).
2002	ADU performed an extensive MBES survey.
2003	Wessex Archaeology (WA) carried out an extensive archaeological assessment, including ground proofing dives and an MBES survey.
2010	The Hampshire and Wight Trust for Maritime Archaeology (now Maritime Archaeology Trust (MAT)) carried out an archaeological survey concerning monitoring (HWTMA 2010). The *First HMS Invincible (1747-58) Her Excavations (1980-1991*) was published (Bingeman 2010) with a full site plan (Figure 104).
2013	Current licensee Daniel Pascoe conducted a cross-disciplinary investigation project, expanding the site plan of recently exposed timbers, on the starboard side (Pascoe 2013). Pascoe Archaeological Services (PAS) has had a significant concern on monitoring and recording vulnerable areas of the site.

2014	Most recently, an extensive survey of areas 2 and 3, part of the starboard has been surveyed by PAS with funding from HE. The NAS and MSDS Marine participated as diving contractors.
2015	Photogrammetric pre-disturbance surveys and monitoring of areas 1, 2, and 3 (PAS 2015).
2016	PAS and Artas Media created an interactive virtual tour with the support of the University of Southampton and funding from HE (PAS and Artas Media 2018).
2017	Excavation of the bow section on Area 1, led by BU and MAST. Grids and the overall area of excavation were recorded with a systematic photogrammetric survey presented in this thesis.
2018	Continuation of the extensive excavation started in 2017 on the bow section moving towards the Stern, aiming to uncover more of the port- amidships area. The opening of a second excavation area Trench 2, revealed, the shot-locker as well as the limber channel, on both the starboard and port sides (larboard[371](Boudriot 1973:31)).

Table 28 Previous work on HMS *Invincible* compiled from: (Bingeman 1981, 1985; J. Bingeman 2010; Ortiz-Vázquez 2013; Pascoe 2013, 2015).

[371] In 1758 this would have been called the Larboard side of the vessel, however, confusion with the word starboard finally led to the adoption of the word port in its stead, and the use of larboard was forbidden by Admiralty Order of 1844 (Boudriot 1973: 31).

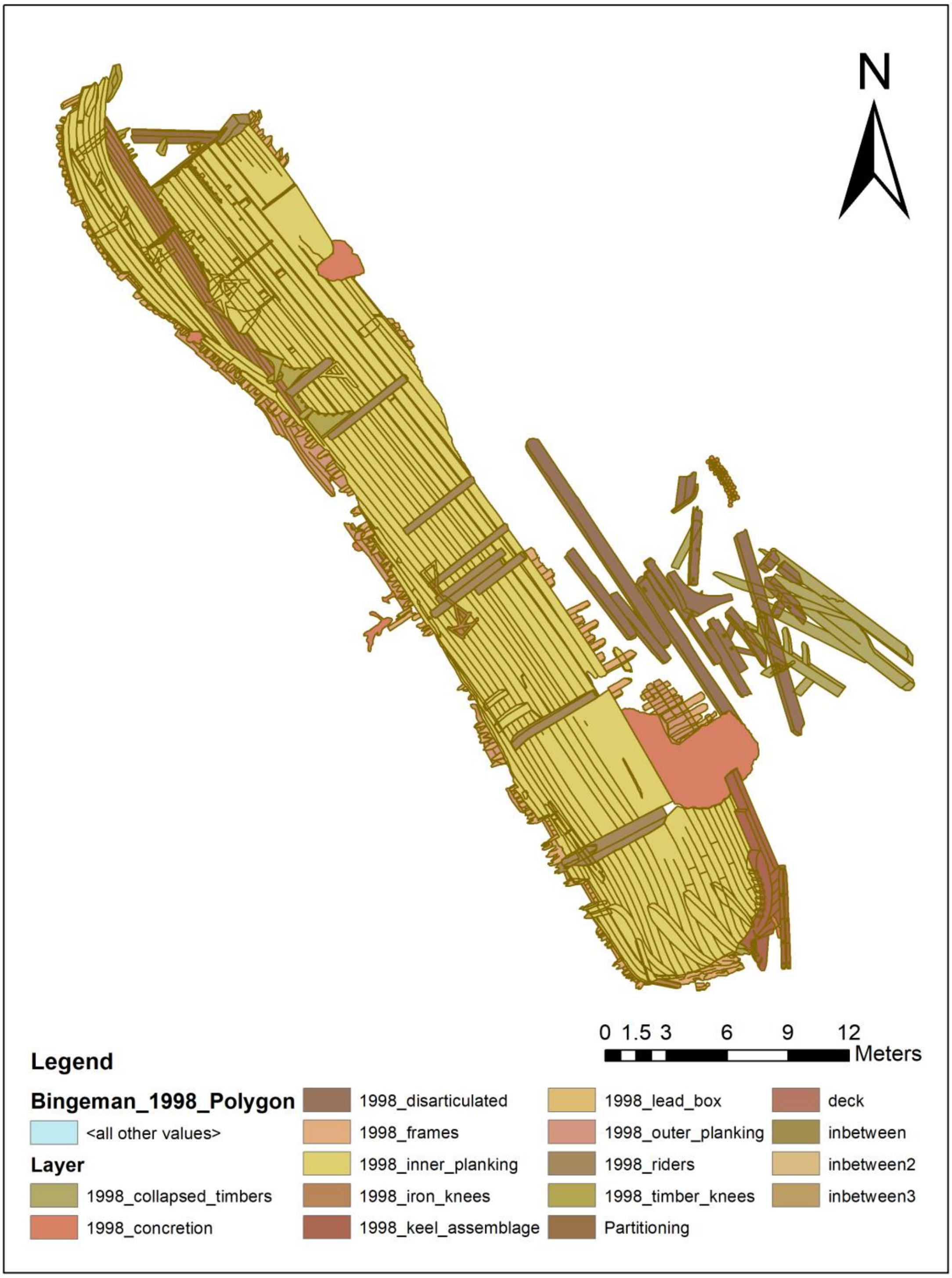

Figure 104. The site plans are based on Bingeman (2010:58) **composite map from 1984-1990. The map has been colour coded, re-adjusted, and georeferenced according to the MBES surveys by PAS and the author of this thesis.**

7.3 Location and Hydrodynamics

The wreck site of the *Invincible* is located on the southern coast of England, in the eastern Solent, approximately 8 km from Portsmouth Harbour (Figure 105). The wreck position was converted from OSGB36 to UTM30N from the designated protected wreck area that covers a radius of 100m from [372] (HE 2018b):

(OSBG36) Easting	(OSBG36) Northing	(UTM 30N) Easting	(UTM 30N) Northing
E 467932.819687	N 93770.9835	638391.46	5622700.78

(WGS84) Latitude	(WGS84) Longitude
50.739585	-1.03864

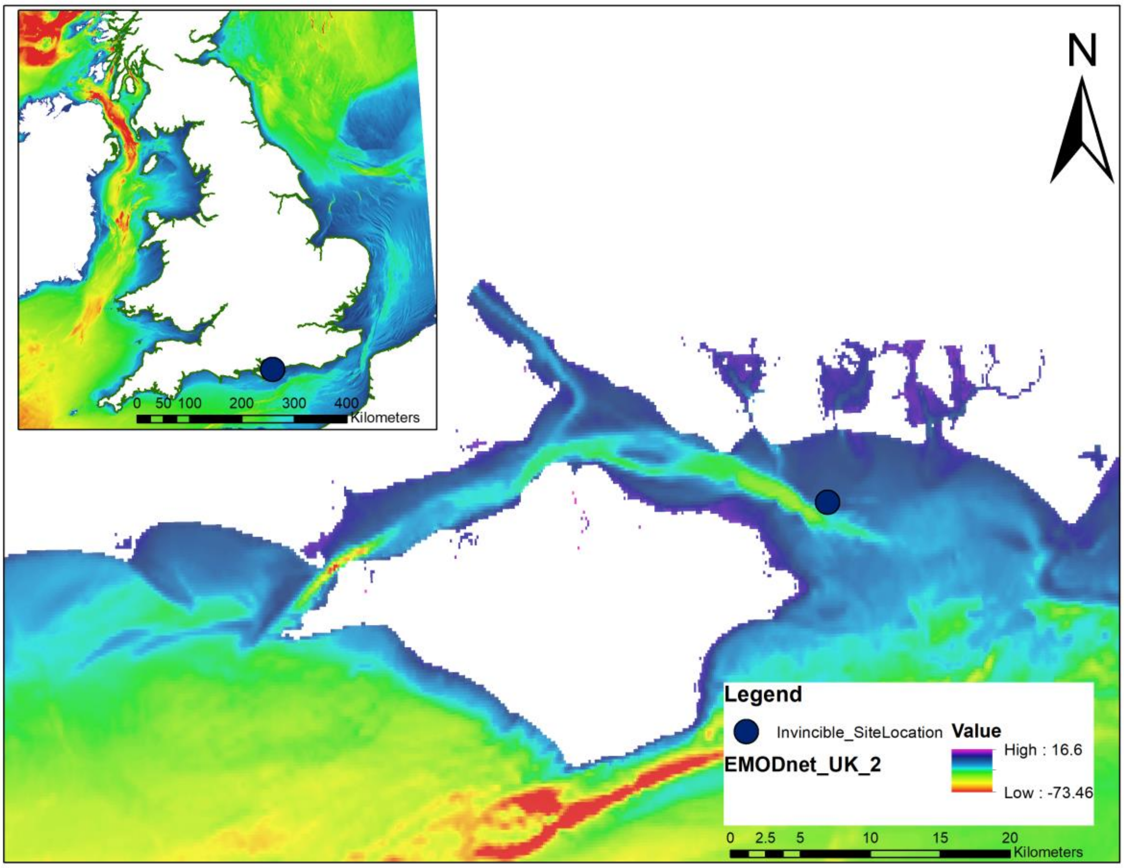

Figure 105. The Southern Coast of England, with the *Invincible* site location according to HE (2018b)**. The projected coastline is the World Vector Shoreline (WVS) from NGA** (National Geospatial-Intelligence Agency

[372] The area is designated under the Protection of Wrecks Act 1973. The statutory Instrument is Order No. 1980/1307.

2018). **The bathymetry and UK territorial waters are sourced from EMODnet** (EMODnet 2018). **Maps created by the author on ArcMap® 10.5.**

7.3.1 Site Conditions

The site is located in a transitional phase: from a moderate-energy environment (M1aM[373]), with an extensive coherent structure and many artefacts, moving towards a high-energy environment with an extensive coherent structure and many artefacts that will gradually affect what is left of the wreck.

The underwater site conditions vary throughout the year, having a direct impact on planning fieldwork. In the UK, as in other places, weather conditions are the principal conditioning factor over diving and vessel survey operations at sea[374].

The *Invincible* is a shallow water wreck that lies at a depth of seven to nine metres CD[375] Portsmouth. During the winter, rough weather restricts diving operations and affects underwater visibility with suspended sediment in the water column. The visibility tends to improve when the weather allows the suspended sediment to settle. However, from June to December, it has been observed that the seaweed is dragged in by the tide and trapped on *Invincible's* protruding structure. This seaweed is either washed out by the tide, or it is buried underneath the mobile layer of sand (these layers of seaweed are thicker during the summer months and less frequent during winter). As the weather improves during the summer, the conditions are more suitable to carry out fieldwork, but the rising temperature of the water also produces bioturbation, affecting light penetration. This was noticeable during the 2016 season when an algal bloom created poor visibility conditions.

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373 See Table 21 in section 4.3

374 All diving operations complied with the Health and Safety Executive (HSE) standards, following the complying with the Approved Code of Practice (ACOP) L104 (HSE 1997), for Scientific Diving. Also with the associated guidance provides practical advice the requirements of the Diving at Work Regulations (DWR) (The Secretary of State 1997). All vessels used for surveys and diving operations strictly follow the Marine Code Approves (MCA) code of practise (MCA 2014).

375 Chart Datum

The combination of some water cycles has been observed to affect or improve underwater visibility. On *Invincible*, during the flood fresh water comes in, and generally, the visibility is better. As it is essential to have stability for the underwater photography, the survey is preferably done during neap tides, allowing the diver to have a controlled swim over the site. Such was the case during the 2017 season, where timing was essential to cover an extensive area of the wreck during the photogrammetric survey.

7.4 Seabed Geology and Sediment Transport

The discussion here of the local seabed geology and sediment transport dynamics will allow for some understanding of the *scrambling processes* that transformed the wreck site. This includes the post-depositional wrecking processes such as waves, currents, seabed movement, and bioturbation.

7.4.1 Geology

The eastern Solent is a high-energy environment with complex local dynamics that determine sediment transport from different harbours and rivers. The *Invincible* site lies on Horse Tail Sandbank, with seabed geology that is composed by slightly gravelly sand, of undifferentiated Holocene deposits (BGS 2018b), according to Folk classification (Long 2006). The Dean and Horse Tail sands are deposited over the Barton Group Bedrock, that is composed of argillaceous[376] (< 32 μm) siliciclastic sedimentary deposits (BGS 2018b; Newforest District Council 2010)(Fig. 108). Sediment analysis from the site reveals that the substrate comprises well sorted, fine-grained (2-25-2.47+) quartzose sands (Quinn et al. 1998:126).

7.4.2 Sediment Transport

In the early 70s, 2.3 million cubic metres of sand was extracted from the Horse and Dean Sand (SCOPAC 2018b), without apparent direct impact on the HMS *Invincible* as this was over 1000m away. Supply volumes have not been computed from Bracklesham, Hayling and Portsea cell but contemporary supply to Horse and Dean Sand must be minimal. This may be because the littoral drift is very weak at Southsea,

[376]Rocks, sediment consisting of, or containing clay.

so input to the tidal channel by westward drift must be negligible (Grontmij 1973; Halcrow 2002; Webber 1982) and the entrance and approach channel is frequently dredged to maintain a depth of at least 12m, thereby entailing output of sediment from the transport pathway (SCOPAC 2018b).

The Dean Sand's movement can be traced by comparing historical charts (Knight 1799; Mckenzee 1786; Sheringham 1848; Vereker 1898), modern charts (ADM 1934, 1970, 1974, 2000, 2005) and MBES from 2013 (CCO 2018) (Figure 107). The sandbank migration is also verified by the site's position relative to the earliest chart from 1786 (Mckenzee 1786) and the most recent survey that plots the entire Dean Sand (CCO 2018). Additionally, the ships logs and Court Martial Minutes refer to the wreck being on the south side of the Horse Tail Sand.

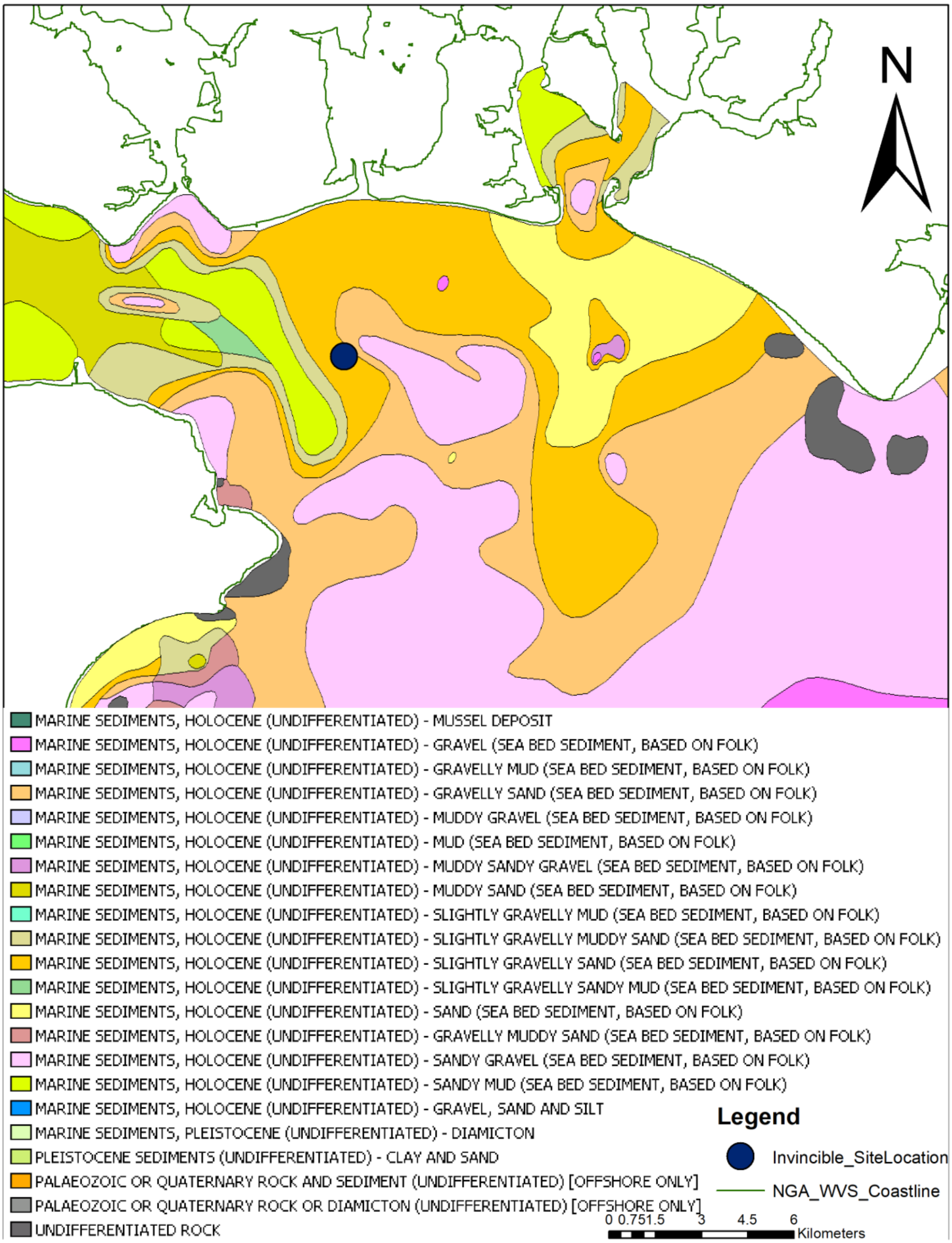

Figure 106. The map shows superficial seabed deposits according to Folk classification. The map was generated with British Geological Service (BGS) offshore marine products and the coastline by NCEI (NCEI 2017)**. The author of this thesis created the figure on ArcMap 10.5®.**

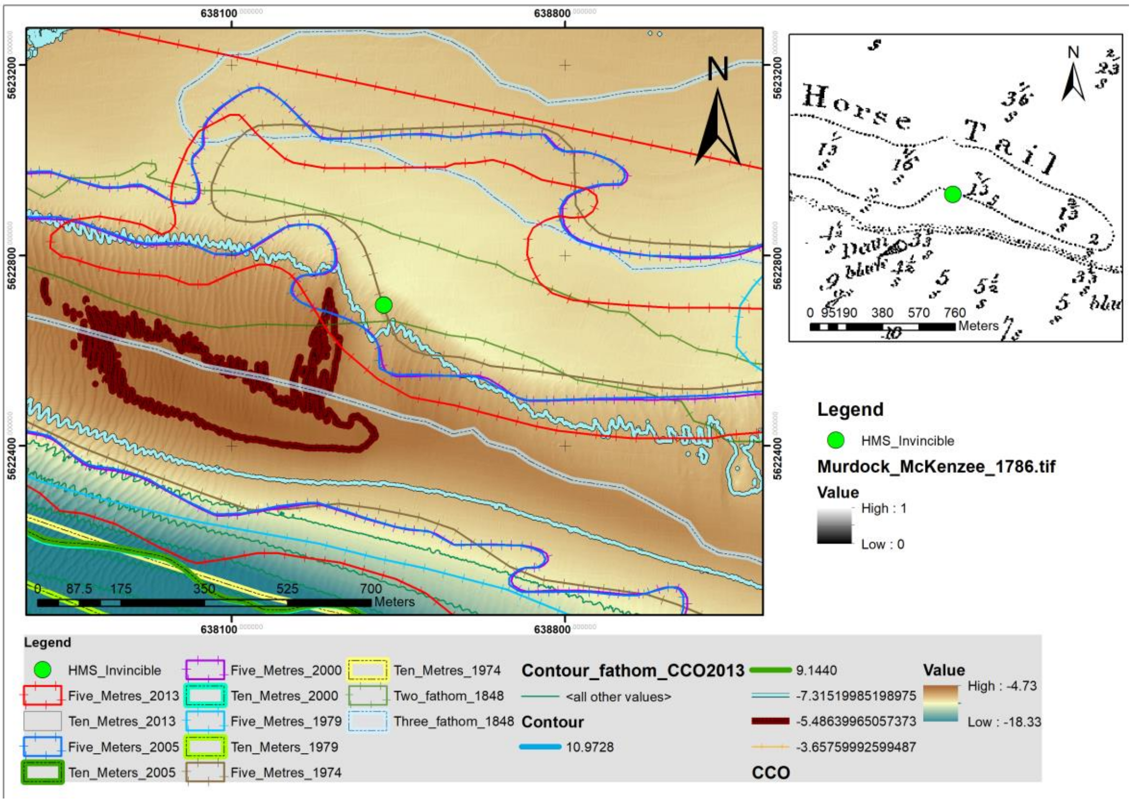

Figure 107. Dean Sand and Horse Tail migration to the South. The map was generated from data derived from historical and modern charts based on MBES CCO data (2013), gathered by the author of this thesis and re-processed (Ortiz-Vázquez 2013)**. The author of this thesis created the figure in ArcMap 10.5®.**

7.4.3 Tides

The tidal currents in the Solent are some of the most complex in the British Isles, with notable differences between the western and eastern Solent, and are further complicated by double high waters (Newforest District Council 2010:23). The ebb tide currents are stronger but of shorter duration than the flood tide currents (SCOPAC 2018b), which is possibly reflected in the crest-to-crest dune migration on site. In the eastern Solent, tidal currents are typically >1.25nts during spring tides in water depths exceeding 5m, which are sufficient to mobilise non-consolidated fine gravel, as well as coarse sand (New Forest District Council 2018:25).

The dominant drift direction is from north-west to south-east between the River Hamble to Gilkicker Point and in an anti-clockwise direction between Selsey Bill and Portsmouth Harbour (Newforest District Council 2010:50). The tidal diamond on *Invincible,* presented by Quinn *et al.* (1998:134) confirms this dominant tidal direction.

7.4.4 Wave and Storminess

Waves within the Solent are controlled by the local fetch and exposure to waves penetrating from the eastern and western Solent entrances. The dominant direction of wave approach in the Solent is from the south-west, although a significant amount of wave energy can also approach from the south and south-east (Newforest District Council 2010:17). This dynamic combination of fetch and waves is visible on the Horse Tail Sands, where the storminess data presented by Quinn *et al.* from 1898 to 1992 revealed that it predominantly comes from a south-westerly direction (Quinn et al. 1998:134).

At a macro-scale, in terms of energy[377] levels (waves, storminess, tides, topography, depth and fetch), the *Invincible* currently lies in a moderate energy infralittoral zone that is transitioning into a high energy infralittoral zone (Figure 108). This represents a serious threat to the coherency of the structure on the wreck. The north end of the Sandbank is moving towards the south, dangerously exposing the starboard side structure.

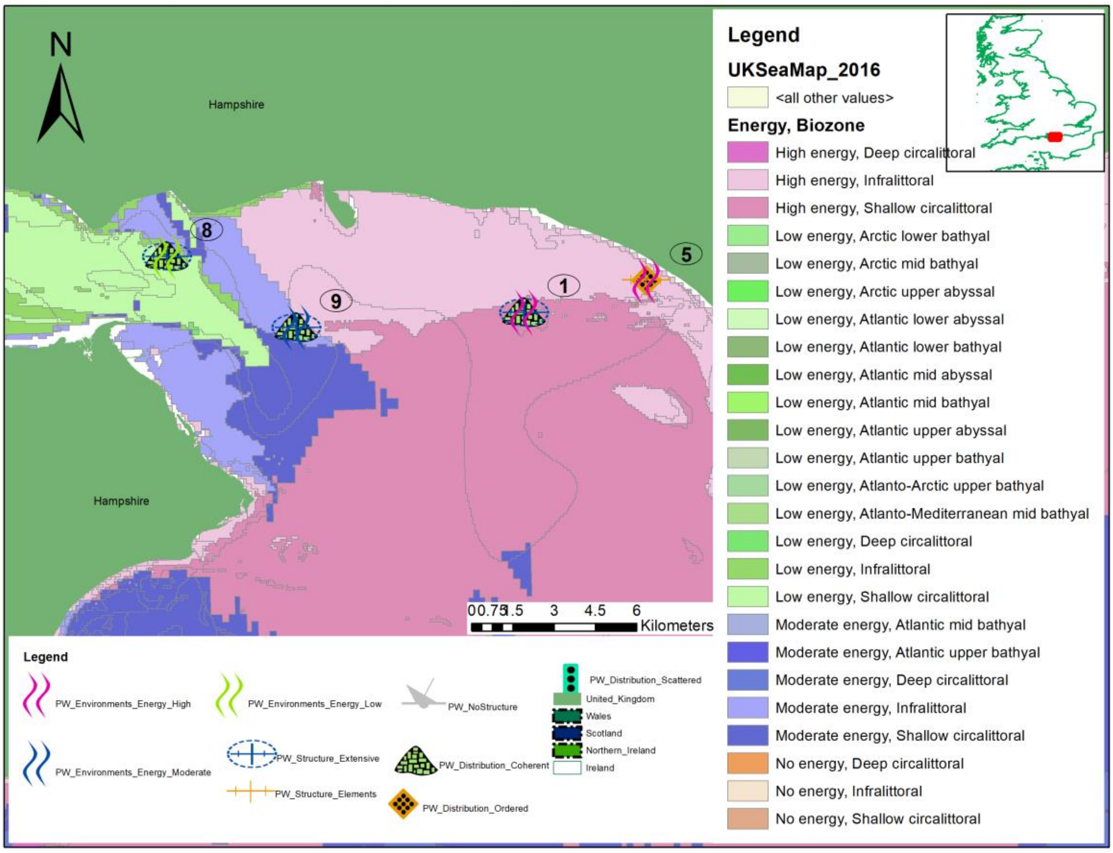

Figure 108. The map show energy levels according to EMODnet (2018), with the PW plotted according to HE (2018) (8) *Mary Rose*, (9) *Invincible*, (1) *A1*, and (5) *Hazardous Prize*. The author of this thesis created the figure in ArcMap 10.5®.

[377] Further discussed in Chapter IV.

7.5 Materials and Methods

The *Invincible* site has been surveyed on numerous occasions with archaeological and geophysical assessments undertaken by the Bingeman (1980-1991), ADU (2002), WA (2003 and 2014), HWTMA (2010), UoS (1998, 2013, 2015, 2016) PAS (2013-2017) and BU-MAST (2017). Consequently, this has produced a vast amount of data, published information and grey literature found in notes, sketches, reports, articles, books, archives and theses.

This chapter ventures to gather and critically analyse the sources above, prioritising the datasets that provide more analytical tools to understand the site formation processes of *Invincible.* However, the main challenge of compiling information produced by different methods is that the data has different standards, resolutions, and quality. Therefore, it was necessary to standardise the material before fully integrating it for re-interpretation. To model the SFP consistently, this project was required to:

- Re-digitise and geo-rectify site plans (direct measurements, planning frames, triangulation and DSM).
- Re-process geophysical data (SSS, MAG, and MBES).
- Re-process previous and newly generated multi-image photogrammetry (MIP).
- Re-asses photos/videos.
- Integrate personal ground-truthing notes from surveys and excavation on site.

The previously mentioned sources provide qualitative and quantitative data for a comprehensive interpretation of the mesoscale site dynamics (Table 29) as well as the intra-site (Table 30 and Table 31). The bed-level change maps are composed by subtracting the repeated surveys areas on both bathymetric and photogrammetric raster layers from each other using ArcMap 10.5®. However, the bathymetric data had to be previously plotted on the same ellipsoid projection and depth (datum) reference, using WGS8430N and CD (MCA 2013). The following tables show the essential information to consider while comparing different surveys on site.[378]

[378] Further discussed in section 3.1.1.1

Invincible Marine Geophysics							
Date	**Survey**	**Equipment**	**Frequency / Resolution**	**Software Process**	**Format**	**Gridded Resolution/ Positioning**	**Datum**
01/02/ 2018(*forthcoming*)*[379]	MBES/ UoS	Reson SeaBat 8125 multibeam (Reson Inc 2002, 2017)	455 kHz	CARIS HIPS® version 8.0.0	(.pds) or (.xtf) into xyz in a Lat., Long. and depth	.20cm/ RTK	WGS843 0N/CD
01/12/ 2016	MBES/ UoS	Reson SeaBat 8125 multibeam (Reson Inc 2002, 2017)	455 kHz	CARIS HIPS® version 8.0.0	(.pds) or (.xtf) into xyz in a Lat., Long. and depth	.20cm/RTK	WGS843 0N/CD
24/11/ 2015	MBES/ UoS	Reson SeaBat 8125 multibeam (Reson Inc 2002, 2017)	455 kHz	CARIS HIPS® version 8.0.0	(.pds) or (.xtf) into xyz in a Lat., Long. and depth	.20cm/RTK	WGS843 0N/CD
02/07/ 2014	MBES/ WA	R2Sonic 2024 (R2 Sonic 2016)	400	HyPack Navigation and QINsy	.xyz	.25cm/ D-GPS	WGS84 30N/ ODN
07/10/ 2013	MBES/ CCO	Kongsberg EM3002D, EM2040D	200 /400 kHz	Uncertain	.xyz ASCII	1m / D-GPS	OSGB36 / ODN
29/09/ 2003	MBES/ WA	Reson SeaBat 8125	455 kHz	HyPack Navigation and QINsy	.pts/.xyz	.50cm / D-GPS	RTK WGS84/ CD
2002	MBES/ ADU	Reson SeaBat 8125	Uncertain	Uncertain	.pts	.50cm /-	WGS84 30N /-
02/07 /2014	SSS/ WA	Klein 3900	20m spacing / 900khz	SonarPro / Coda GeoSurvey	(.xtf) into xyz in a Lat., Long. and depth	D-GPS	WGS84 30N /-
02/07 /2014	MAG/ WA	Geometrics G-882 Caesium Vapour	10Hz	Geometrics MagLog Lite	.GEOMAG, converted to .txt	D-GPS	WGS84 30N /-

Table 29 MBES time-series surveys on *Invincible*. The information was gathered from several reports and the data from several archives. ADU (2002) and WA (2003 and 2014) data was kindly provided by HE, from the Historic England Archive in Swindon. Dr Justin Dix, based at the National Oceanography Centre Southampton

[379] Scheduled to happen this year on R.V. *Callista* based at NOCS-UoS.

(NOCS) at the University of Southampton, kindly provided UoS data (2015, 2016). The Channel Coastal Observatory (CCO) data is available at their website (CCO 2018).

Invincible **Multi-Image Photogrammetry (MIP)**							
Date	**Survey**	**Equipment**			**Task**		**Product**
		Camera/ Lens	**Housing/ Dome**	**Lights/ Strobes**	**Data Capture**	**Survey Area**	**Format / Converted**
8th-9th-23th-24th-28th/05/2018	BU	GoPro Hero6 Black ™ /Standard GoPro lens with added INON UFL-G140 wet-lens (INON 2018)	GoPro ™ Housing and flat port (GoPro 2018)	Series 5 k ™ (Anchor Dive Lights 2018)	Time-lapse	Area 1/Bow (Trench 1) And Trench 2	JPG
24th/05/18	BU	Nikon D800 ™ (Nikon 2018e) / AF-S NIKKOR 14-24mm f/2.8G ED (Nikon 2018a)	Sea & Sea MDX D800 (Sea & Sea 2018b) / Acrylic 10" dome with a port base (Sea & Sea 2018a)	Stills	-	Area 1/ Bow and extended area*	RAW/TIFF
22/05/2017	BU	Nikon D800 ™ (Nikon 2018e) / AF-S NIKKOR 14-24mm f/2.8G ED (Nikon 2018a)	Sea & Sea MDX D800 (Sea & Sea 2018b) / Acrylic 10" dome with a port base (Sea & Sea 2018a)	-	Stills	Area 1/Bow	RAW / PNG
17/05/2017	PAS	GoPro Hero4 Black ™ /Standard GoPro lens with added INON UFL-G140 wet-lens (INON 2018)	GoPro ™ Housing and flat port (GoPro 2018)	Series 5 k ™ (Anchor Dive Lights 2018)	Time-lapse	Area 1/Bow	JPG
02/06/2016	PAS	GoPro Hero4 Black /Standard GoPro lens with added INON UFL-G140 wet-lens (INON 2018)	GoPro ™ Housing and flat port (GoPro 2018)	Series 5 k (Anchor Dive Lights 2018)	Time-lapse	Area 1/Bow	JPG
16/05/2016	PAS	Nikon D610(Nikon 2018d) / AF Nikkor 20mm f/2.8D (Nikon 2018b)	200 FL Ikelite TTL / 8" dome port with extension ring	Ikelite / Ikelite DS161 Strobe	Stills	Area 1/Bow	RAW / PNG
15/05/2016	PAS	GoPro Hero4 Black /Standard	GoPro ™ Housing and flat	Series 5 k (Anchor	Time-lapse	Area 1	JPG

		GoPro lens with added INON UFL-G140 wet-lens (INON 2018)	port (GoPro 2018)	Dive Lights 2018)			
11/07/15	PAS	GoPro Hero4 Black /Standard GoPro (Wide FOV-17.2mm)	GoPro Housing and flat port	-	Video	Area 1 /Bow	Mp3/JPG
2014	PAS	Canon S110 / Standard 35mm lens	Ikelite housing with WD-3 wide angle dome port (Ikelite 2018a, 2018b)	-	Stills	Area 2	RAW / TIFF

Table 30 Photogrammetry data sets, equipment details and survey areas.

Invincible* *Site Plans					
Date	**Survey**	**Equipment**	**Task**		**Product**
		Method	**Data captured**	**Survey area**	**Format/converted**
1980-1990	Bingeman	DSM/direct measurement	Hand drawing and plotting	Port-side structure / Part of starboard	Digitised compiled images .png / Vectorised Cad files .dxf
2012	Pascoe	DSM/direct measurement /planning frames	Hand drawing and plotting	Area 2	Digitised compiled images .png / Vectorised Cad files .dxf
2012	Pascoe	DSM/direct measurement /planning frames	Hand drawing and plotting	Area 3	Digitised compiled images .png / Vectorised Cad files .dxf
2014	Pascoe	DSM/direct measurement /planning frames	Hand drawing and plotting	Area 2 and 3	Digitised compiled images .png / Vectorised Cad files .dxf
2015/16	PAS	MIP /DSM	Remote sensing and digitally plotted	Area 1, 2 and 3	3D models Digitised compiled images .png / Vectorised Cad files .dxf
2017/18/19	BU/MAST	MIP /DSM	Remote sensing and digitally plotted	Area 1 (Trench 1), and Trench 2	3D models Digitised compiled images .png / Vectorised Cad files .dxf

Table 31. Site plans for *Invincible*

7.6 Results

This section is divided into pre-disturbance and post-disturbance surveys, presenting comparative results by emphasising the importance of both research stages. This approach offers further insight for understanding the site dynamics and its direct impact on the wreck. The analysis considers the effects of both the *extracting filters*[380] and the *scrambling devices*[381] on macro, meso and intra-site levels.

7.6.1 Pre-disturbance Surveys

The pre-disturbance surveys are divided into two categories to simplify their description and presentation. The first, marine geophysics, provide a broad context perspective, focusing on the macro-scale site dynamics. The second, the MIP (Multi-Image Photography) time-series directly correlates the ships' structure with the bed-level changes. Furthermore, the comparative multi-image photogrammetry models created as part of the excavation takes us through to the post-disturbance surveys. Presenting a high-resolution survey that demonstrates the real vulnerability of the UCH on *Invincible*.

7.6.2 Multi-beam Eco Sound (MBES) Time-series

The macro and mesoscale dynamics of the sea bed-level changes are the central points of attention of the MBES time-series plotting areas of sediment erosion (loss) and accretion (gain). These datasets provide extensive coverage that goes beyond the designated protected wreck area (Table 29). They are presented first because the 2016 MBES carried out by UoS was essential to geo-reference all of the other datasets (site plans, photogrammetry, *in situ* observations).

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380 *Extracting filters*, defined as mechanisms that took material away from the wreck, such as the nature of the wrecking process, salvaging, and disintegration of objects (Muckelroy 1978:165-169; Stewart 1999:567). Secondly, *scrambling processes* that begin during the process of wrecking. This included the post-depositional wrecking processes that are constituted of waves, currents, seabed movement, and bioturbation (Muckelroy 1978:169-182; Stewart 1999:567).

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Nowadays high-resolution MBES surveys have become a standard archaeological mapping technique on shipwrecks as they have been demonstrated to be a cost-effective tool. However, over the past decade repeated MBES surveys on sites are less frequent than desirable, and only a few sites have had that type of survey (Astley 2016; Astley et al. n.d.; Bates et al. 2011; Plets et al. 2011; Zhao et al. 2017). Luckily, *Invincible* has several surveys that allow annual (2013-2014; 2014-2015; 2015-2016), decadal (2003-2013) and a quasi-decadal (2003-2014) time-series of the changes on site.

Different institutions, with various standards and coverage areas, carried out the MBES surveys for *Invincible* (Table 26). The differences include resolution, format, survey equipment, positional and depth datums that required re-processing to standardise the results[382]. During this process, the earliest survey done by ADU (2002) was discarded for this study (Figure 109 (A)). This was because of insufficient coverage and point density as well as the uncertainty of the depth datum.

The other MBES datasets consistently show the elongated coherent port side structure aligned with the edge of Horse Tail Sand. This is likely to be because during the wrecking event she struck with her bow first onto the southern side of Horse Tail and the rest of the hull was pushed by the weather against the sandbank (Figure 109). This would position the hull parallel to the sand before she took water and sank into that spot. The scattered starboard side lies to the north due to the predominant storm direction, as shown by storm data (Figure 110 (F) (Quinn et al. 1998)), which scattered her remains. The structural integrity is reported by Bingeman (2010) and later surveyed by Pascoe (PAS 2015; Pascoe 2013; Pascoe Archaeology 2018b).

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[382] Further explaination on marine geophysics and MBES in section 3.3.1.1

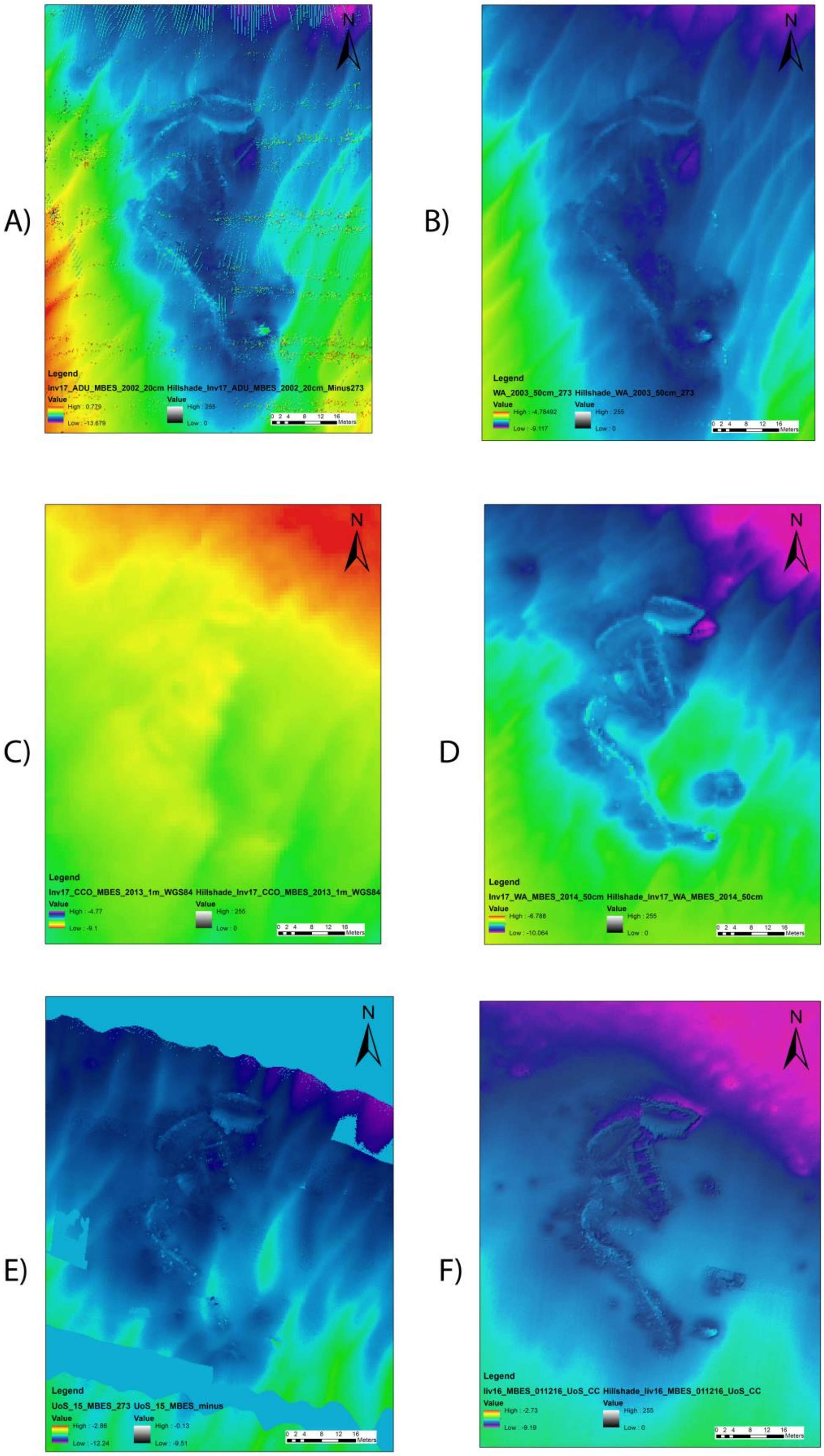

Figure 109. The figure shows MBES surveys on *Invincible* carried out in different years and by different contractors A) 2002 ADU, B) 2003 WA, C) 2013 CCO, D) 2014 WA, E) UoS 2015 and F) 2016 UoS. The maps have been geo-referenced to WGS84 30N and depth values are in CD Portsmouth. The author of this thesis created the map in ArcMap 10.5®.

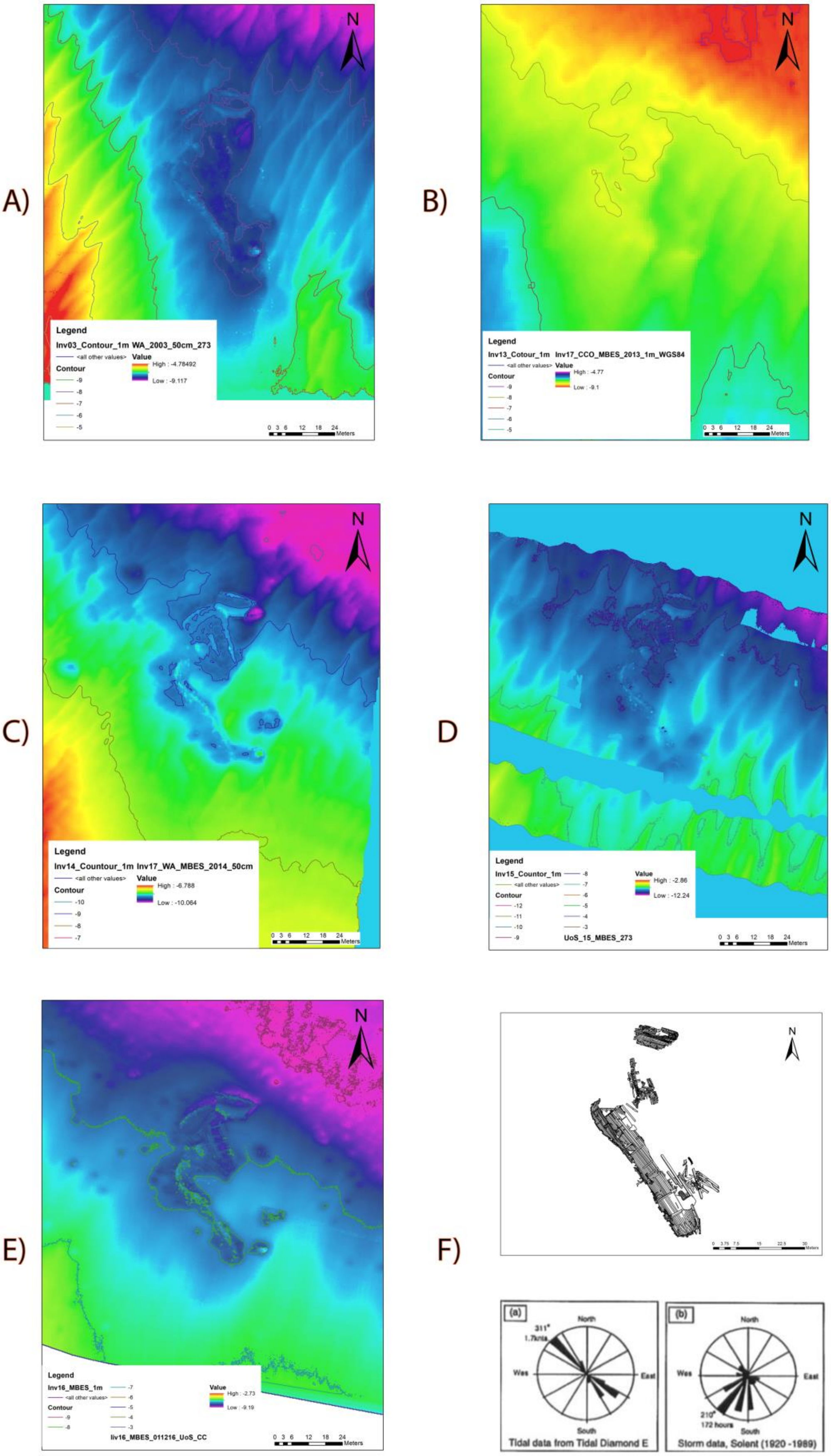

Figure 110. The figure presents the MBES datasets with a contour each metre (-6, -7, -8, -9 and -10). The maps show: A) WA 2003, B) CCO 2013, C) WA 2014, D) UoS 2015 and E) UoS 2016. The tidal diamond (F), and storm data (F) is from Quinn et al. (Quinn (2006). The author of this thesis created the map in ArcMap 10.5®.

The general morphology of the sandbank presents a ridge to the west of the port side structure, with dune crests that run in a southeast-northwest direction determined by the tidal movement. The seven-metre contour line delineates this ridge, which has progressively shifted towards the west (Figure 110 (A-F)). The edge of the northern side of the bank is represented by the eight-metre contour line (Figure 110 (A-F)). The slope analysis (5° intervals), also illustrates the seabed morphology by enhancing the dunes on the ridge and the edge of the sandbank (Figure 111). The orientation of the crest of the dune seems to be directly related to the tidal flow that runs in a northwest-southeast direction. This effect has also been observed by Ernstene *et al.* (2005) on tidal inlets as well as on other wreck sites (Astley 2016; Quinn et al. 2007).

The changes to the morphology of the sandbank become evident by viewing sediment change rates on the decadal and quasi-decadal (13 years) periods (Figure 112 (A)). These show a significant accretion of sediment to the south of the primary structure, most likely coming from the northern edge of the Horse Tail.

A visibly marked slope delineates the northern edge of the sandbank (Figure 110), along with the eight-metre contour (Figure 110). It is also evident how this eight-metre contour progressively shifts closer to the wreck site (Figure 110). In 2016, a new nine-metre contour line appears less than 20 metres away from the wreck (Figure 110 (E)). The slope maps also reveal the edges of the wreck structure more noticeably by 2016 (Figure 111 (A) and (E)). This confirms *in situ* observations of scouring around the wreck's structure, especially around the northern area (Area 3) (PAS 2015; Pascoe Archaeology 2018b).

The Horse Tail has a general tendency to migrate south. However, this movement can be altered by storm activity that generates local dynamics, covering and uncovering parts of the wreck.

In sum, the MBES time-series clearly explains the long-term trend of the *Invincible* wreck site, emphasising the migrating sandbank that is gradually shifting in a south-westerly direction. However, localised changes in the structure are difficult to monitor with the resolution that our MBES datasets provide (0.2 m).

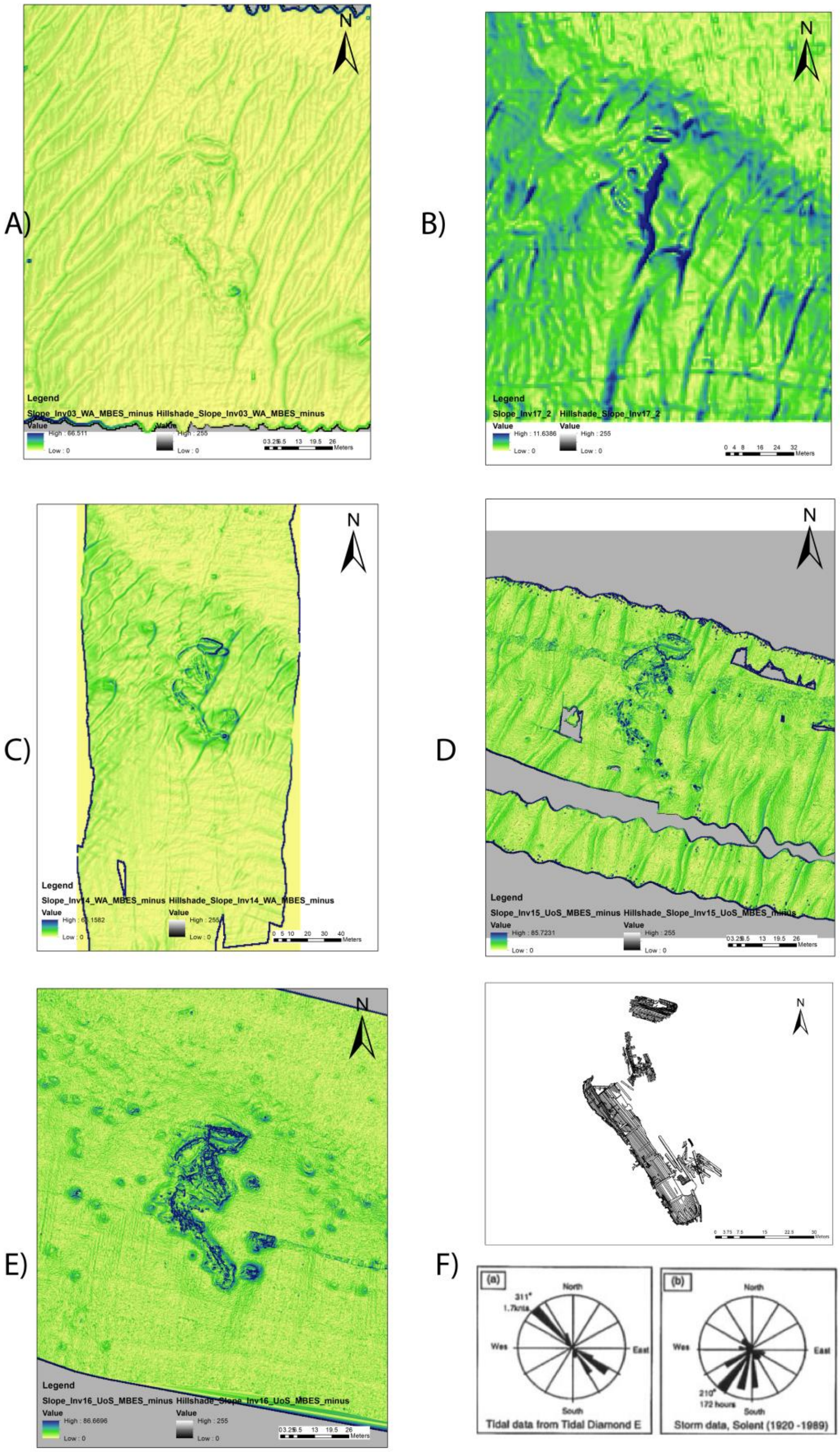

Figure 111. The figure shows a slope analysis of the MBES surveys on *Invincible* carried out in different years, highlighting structural features and sand forms. A) 2003, WA), B) 2013 CCO, C), 2014 WA, D) UoS 2015, E) UoS 2016 and F) Site Plan a well as the prevailing tide and wind on site by Quinn (2006). The maps have been geo-referenced to WGS84 30N and depth values are in CD Portsmouth. The author of this thesis created the map in ArcMap 10.5®.

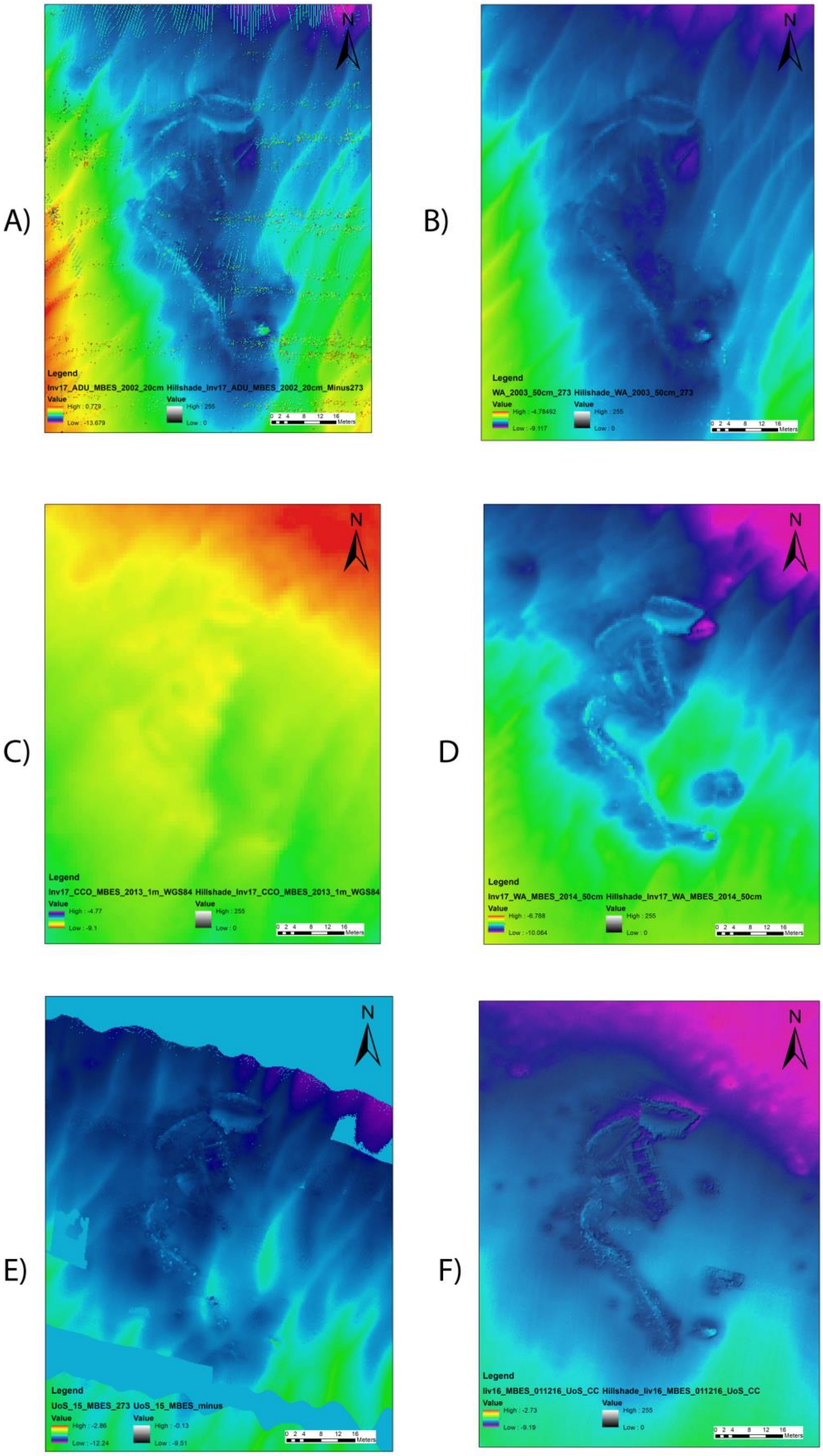

Figure 112. The figure is showing minus calculation with a spatial analyst tool (ESRI 2018c) **done in ArcMap 10.5® for the MBES dataset mentioned in table 16. MBES time-series are showing change rate and scouring patterns. A) 10-year period from 2003 to 2013, B) 11-year period from 2003 to 2014, C) Annual change period from 2013 to 2014, D) Annual change from 2014 to 2015, E) Annual period from 2015 to 2016 F) Site-plan with prevailing wind and tide patterns** (Quinn et al. 1998)**. The author of this thesis created the map in ArcMap 10.5®.**

7.6.3 Multi-image Photogrammetry (MIP) Time-series

Multi-image photogrammetry (MIP) has become an increasingly popular method for recording underwater cultural heritage (UCH), specifically on shipwrecks. The advances in technical capabilities of computer-generated imagery in recent years have facilitated the possibility to record extensive areas at high-resolution with this cost-effective tool. The majority of the published sources have focused on the technicalities of acquisition and processing or the methods accuracy (Aragón et al. 2018; Demesticha et al. 2014; Drap 2012; Drap, Merad, et al. 2015; Eriksson and Rönnby 2017; Henderson et al. 2013; Historic England 2017; Jones 2016; McCarthy and Benjamin 2014; Pacheco-Ruiz, Adams, and Pedrotti 2018; Radic Rossi et al. 2019; Semaan and Saeed Salama 2019; Yamafune 2016; Yamafune et al. 2016; Yamafune, Torres, and Castro 2017). The main objective of these articles is to propose a series of workflow-methods in a variety of conditions and, in essence, to measure its use for site interpretation. Some authors mention the capabilities of photogrammetry for site management, public engagement or shipwreck reconstruction (Balletti et al. 2016; Yamafune et al. 2017). However, this chapter attempts to go beyond that by presenting further analytical capabilities of integrating multi-image photogrammetry with other sources for site formation processes interpretation.

The multi-image photogrammetry time-series started with recording and assessing the *Invincible's* wreck to demonstrate its vulnerability. During 2014, the first trial was carried out on a section of Area 3, on the northern end of the wreck (Table 30). It became evident that MIP was a cost-effective tool that could cover large expanses in a relatively short time with a high level of detail, impossible to capture with traditional drawing methods. However, limitations were encountered mainly associated with low-visibility and bioturbation. In addition to a large amount of seaweed moving across the site, dragged by the tide. More trails were run during 2015, which successfully recorded 11.80m^2 of Area 1 (Figure 113 (A)). These promising results triggered the idea of carrying out an extensive survey of Area 1 and Area 3, which was achieved during the 2016 season. During this fieldwork season, a ground control point network (GCP) was established to scale and guarantee accuracy on the photogrammetric surveys, with direct measurement calibration. The network was extended during the excavations of 2017 and 2018, as more of the structure became exposed. The methodology and workflow are explained in section 3.3.3.3, and the spatial accuracy of the 2016 survey is further discussed by Jones (2016). These datasets were used to build an interactive virtual tour launched in 2017 by PAS (Pascoe Archaeology 2018b)[383]. The total area of coverage for Area 1 was 77.90 m^2 (Figure 113 (A)) and Area 3 was 46.99m^2 (Figure 114 (B)).

During the excavation of 2017, Area 1 covered 131.39m^2 of the survey (Figure 113 (C)). In 2018, the same part of Area 1 was surveyed 189.60 m^2 (Fig. 115 (D)) and Trench 2 163.61 m^2 (Figure 114 (C)) and Figure 116 (B)).

[383] Follow the link to the virtual tour (https://www.cloudtour.tv/invincible). The virtual trails were kindly funded by HE (James 2018; James and Cox 2017).

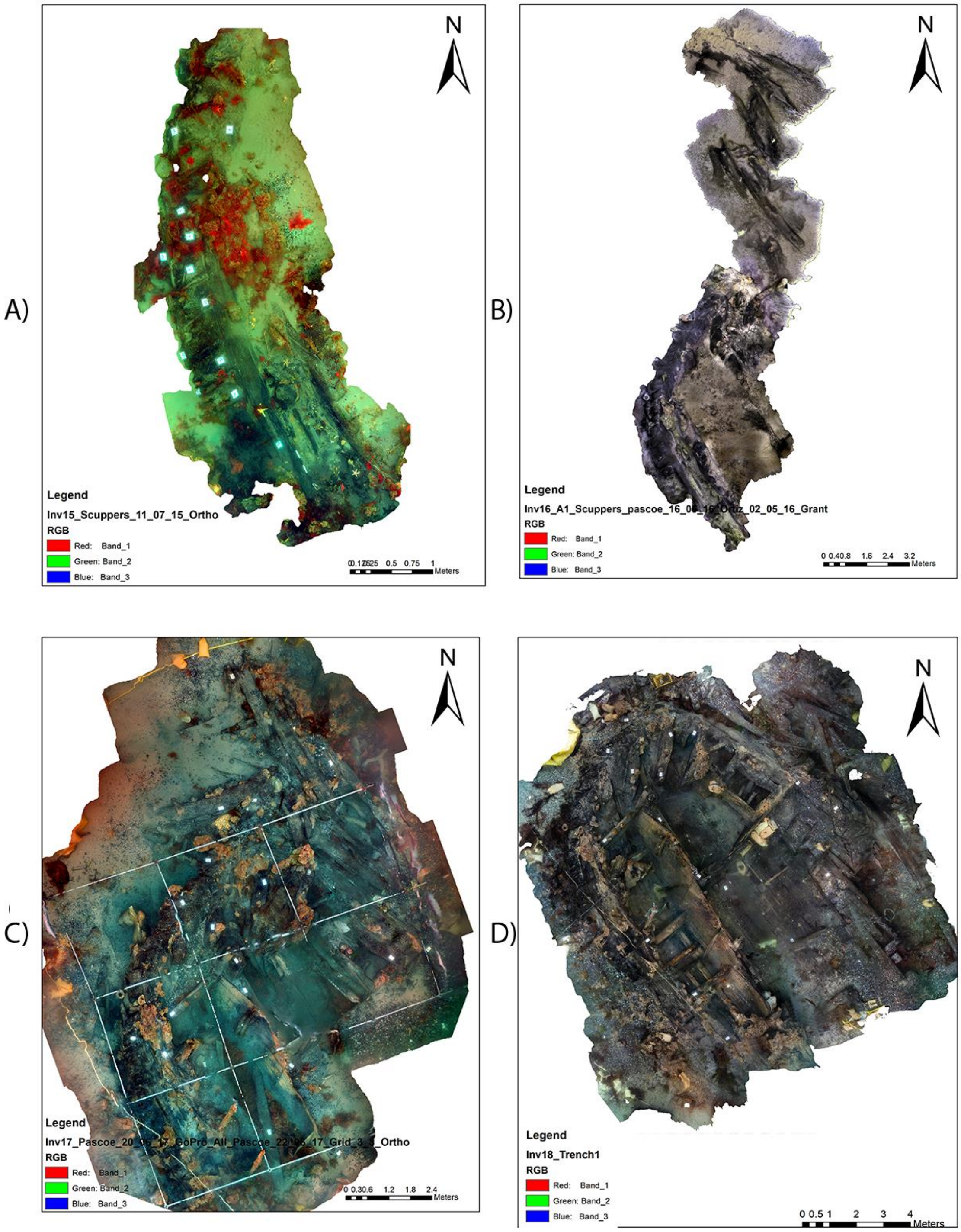

Figure 113. The orthophotos were made with Agisoft Metashape Pro v1.5 ®, the maps were generated with ArcMap 10.5®. A) Area 1 2015, B) Area 1 2016, C) Area 1 2017 and D) Trench 1 (Area 1) 2018.

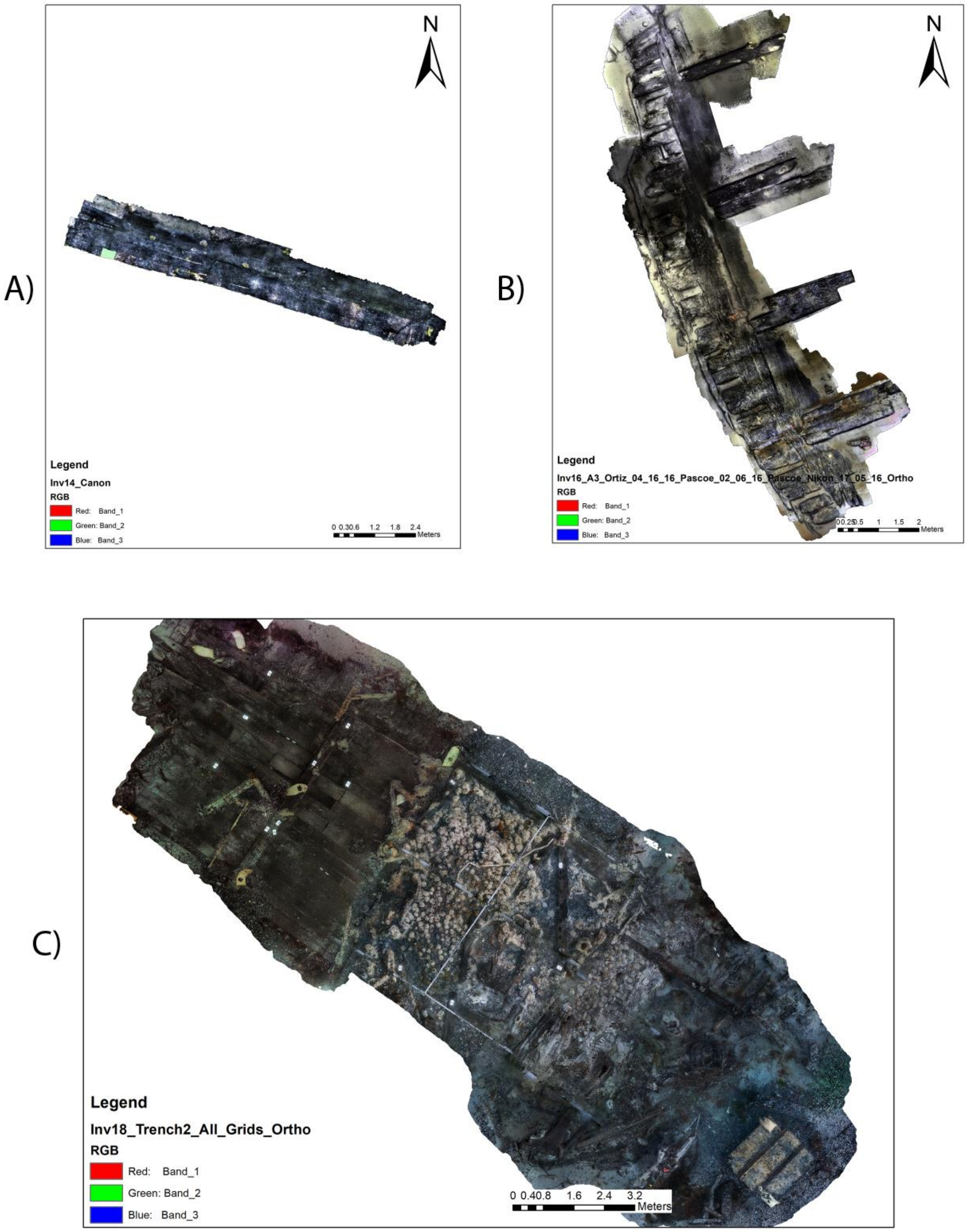

Figure 114. The orthophotos were made with Agisoft Metashape Pro v1.5 ®, the maps were generated with ArcMap 10.5®. Geo-referencing was in WGS84 UTM 30N, depth based on MBES UoS 2016 (CD). A) Area 2 2014, B) Area 3 2016, C) Trench 2 2018 and D) Area 1 2018.

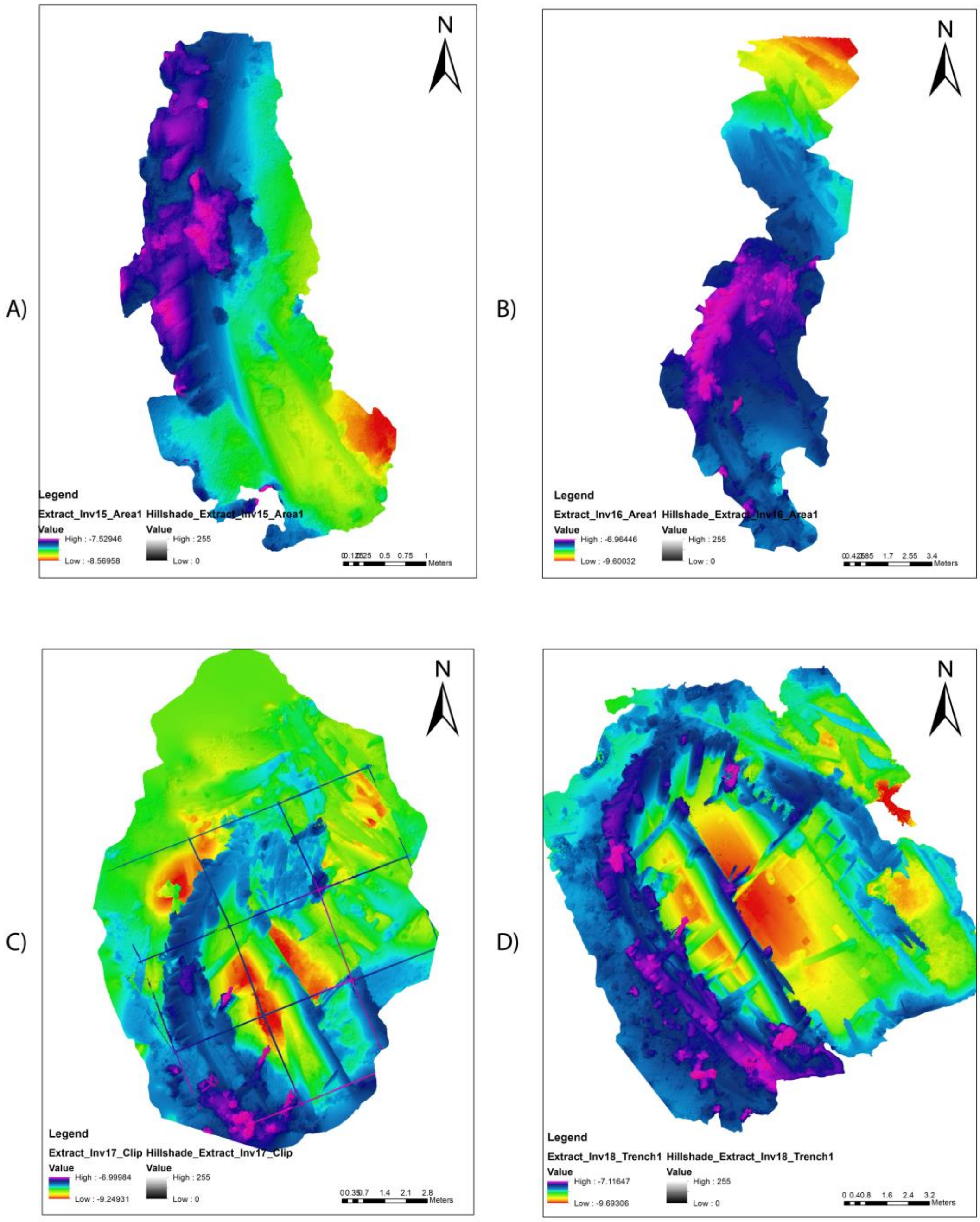

Figure 115. The DEM models were generated and geo-referenced in WGS84 30N, with Agisoft Metashape Pro v1.5 ®. A) Area 1 2015, B) Area 1 2016 C) Area 1 2017, and D) Area 1 2018. The author of this thesis created the map in ArcMap 10.5®.

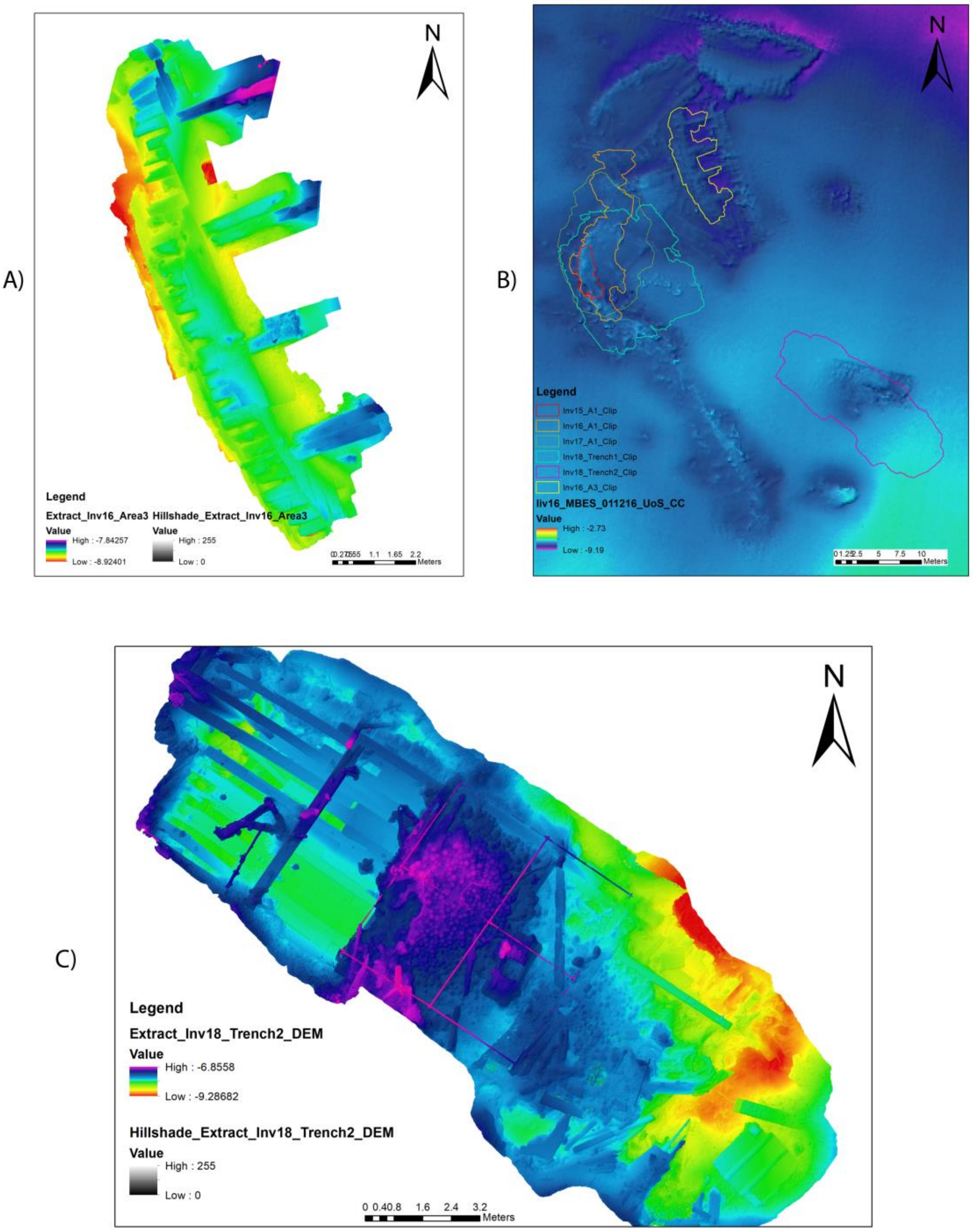

Figure 116. The DEM models were generated and geo-referenced in WGS84 30N, with Agisoft Metashape Pro v1.5 ®. A) Area 1 2016, B) Area 1 coverage of each survey, and C) Trench 2 2018. The author of this thesis created the map in ArcMap 10.5®.

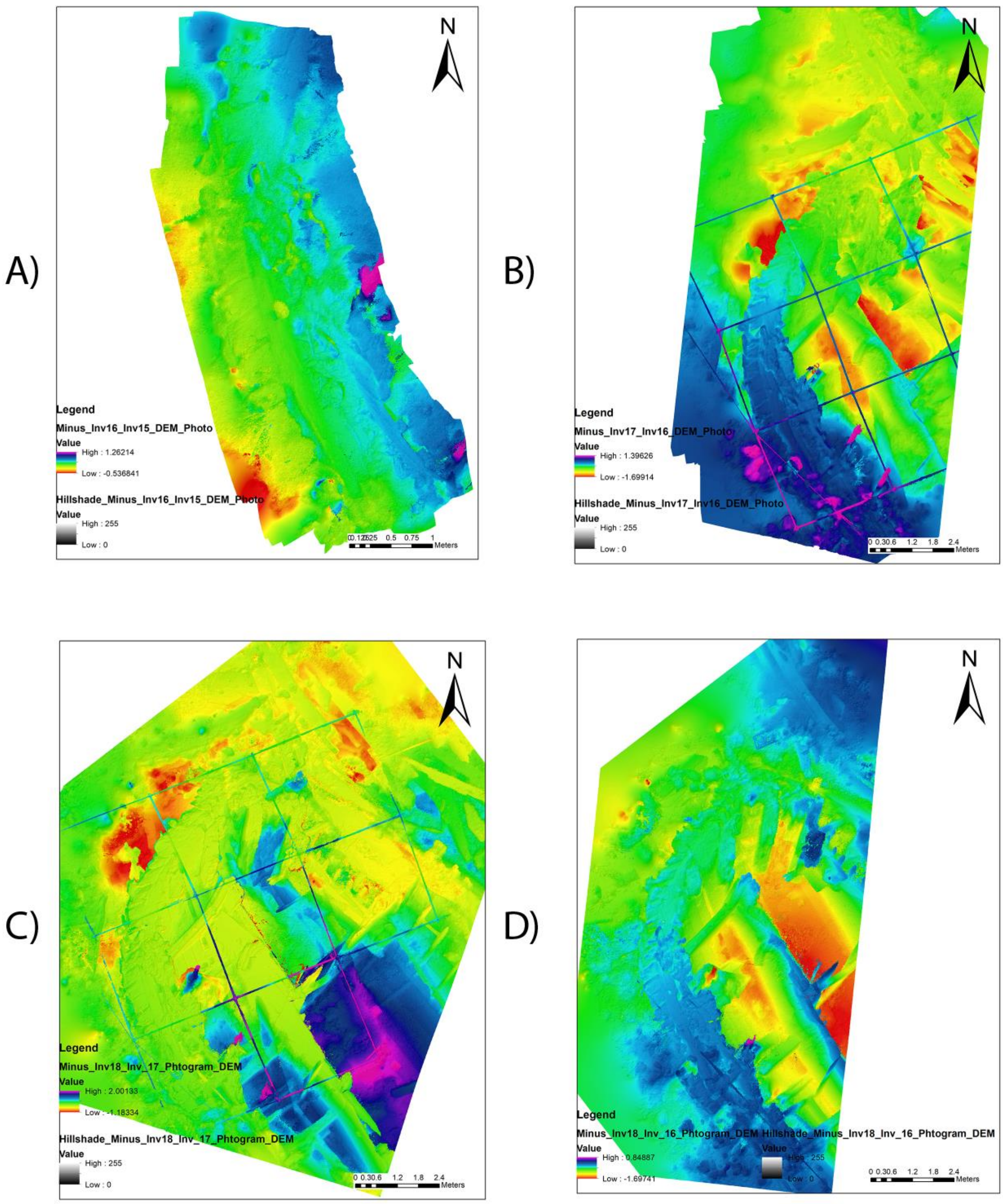

Figure 117. The multi-image photogrammetry time-series with annual intervals. A) 2015-2016, B) 2016-2017 C) 2017-2018, and D) Bi-annual chance 2016-2018. The DEM models were generated and geo-referenced in WGS84 30N, with Agisoft Metashape Pro v1.5 ®. The raster calculation was done in ArcMap 10.5®.

Once the ground control network (GCN) is established, based on the MBES, multi-image photogrammetry is capable of generating high-resolution DEMs with millimetre accuracy of the bed-level surface and archaeological feature [384]. From Agisoft

[384] See section 3.3.4

Metashape Pro v1.5 ®, it was possible to generate a single band raster[385] projected into WGS84 30N, including the added depth values in Chart Datum derived from the MBES. The DEMs are then compared using the spatial analyst tool in ArcMap® (ESRI 2018b). By subtracting the yearly-based surveys they reveal areas of sediment mobility as well as changes to the wrecks' structure (Figure 117).

The multi-image photogrammetry time-series were categorised into 20 mm depth differences. The red values represent areas of erosion or loss of sediment, while the blue values show accretion of sediment. To highlight areas of the uncertainty level (from <20 mm-0 and 0-(-) 20 mm), a purple colour was assigned on the maps (Figure 117). From 2015-2016 (Figure 117 (A)) sediment covered the survey area with sand which is also visible on the MBES time-series (Figure 117 (D)). On the bi-annual time-slice, superficial sediment was removed by the excavation to reveal the structure. Some areas only present minor changes, but the most revealing fact is the amount of sediment that covers the rest of the structure of Area 1, which lies below the gun deck (Figure 117 (C) and (D)). The hold of the ship is covered by 1.7 m of sediment that has backfilled during the post-deposition process (Figure 117 (D)). This backfill was removed during the excavation of 2017 and 2018 to record in detail the port side of the ship, revealing the ship's stores. *In situ* observations noted that approximately 20-30mm of sand preserved the inner planking, pinewood panels, as well as other vulnerable features (such as artefacts that are further discussed in this chapter). The MBES time-series was unable to reveal this loose sand layer or correlate it directly with specific features of the structure. Until this point, the only method to record this mobile layer of sand was the direct measurement of sediment monitoring points (SMP) (Camidge 2017; Pascoe 2013; Satchell and Whitewright 2014; Whitewright and Satchell 2015). However, such methods only take a single point and are subject to human error as they rely solely on the divers' reading of the measurement. On the other hand, a DEM presents volumetric analysis with millions of points to create a surface with accurate readings. Therefore, the comparative analysis of multi-image photogrammetry DEM models offers a far more enlightening method to measure sediment loss or accretion by areas.

[385] The stretched renderer displays continuous raster cell values across a gradual ramp of colours. The stretched renderer is used to draw a single band of continuous data, with a large range of values, such as elevation models.

7.6.4 Post-disturbance surveys. Excavating and Recording HMS *Invincible*

Bingeman and his team carried out a series of excavations on *Invincible* from 1980 to 1996, with a series of trenches across the site. Throughout this period, the structure was recorded as they excavated. In 1990, Bingeman published a compiled site plan that combined previous efforts (Bingeman 2010). Although they were produced using DSM control points and drawn to scale, they had no exact geo-referencing. Therefore, plotting the exact location of previous excavation trenches, and the structural features, was challenging (See section 7.6.3).

After the 2017 and 2018 excavation, it was possible to create high-resolution orthophotos and a DEMs of the whole extent of the excavation covering 131.39 m^2 in 2017 and 189.60 m^2 in 2018 of Area 1[386]. Additionally, a completely new area was excavated during 2018, named trench 2, covering 163.61 m^2 (Figure 114 (C)).

The exact positioning of the previous trenches required re-assessing with the newly available data as well as *in-situ* observations during the excavation of disturbed layers and non-disturbed layers. There was a definite overlap between G6 (2017)-TB (1982), G7 (2017) - TB (1983), because of the intrusive 1980s rubbish found during the excavation, probably deposited there by sewage (Figure 118). However, numerous archaeological artefacts were in grids G2, G3, G5, G8, G10, and G15, which had unexcavated areas, as well as grids (-) G1- (-) G5 following the disarticulated bow section.

[386] Full rendered animation is available at: (https://vimeo.com/257148810) (https://vimeo.com/280600862) (The video has private view settings, use password: Invincible 1744 and Invincible 1758).

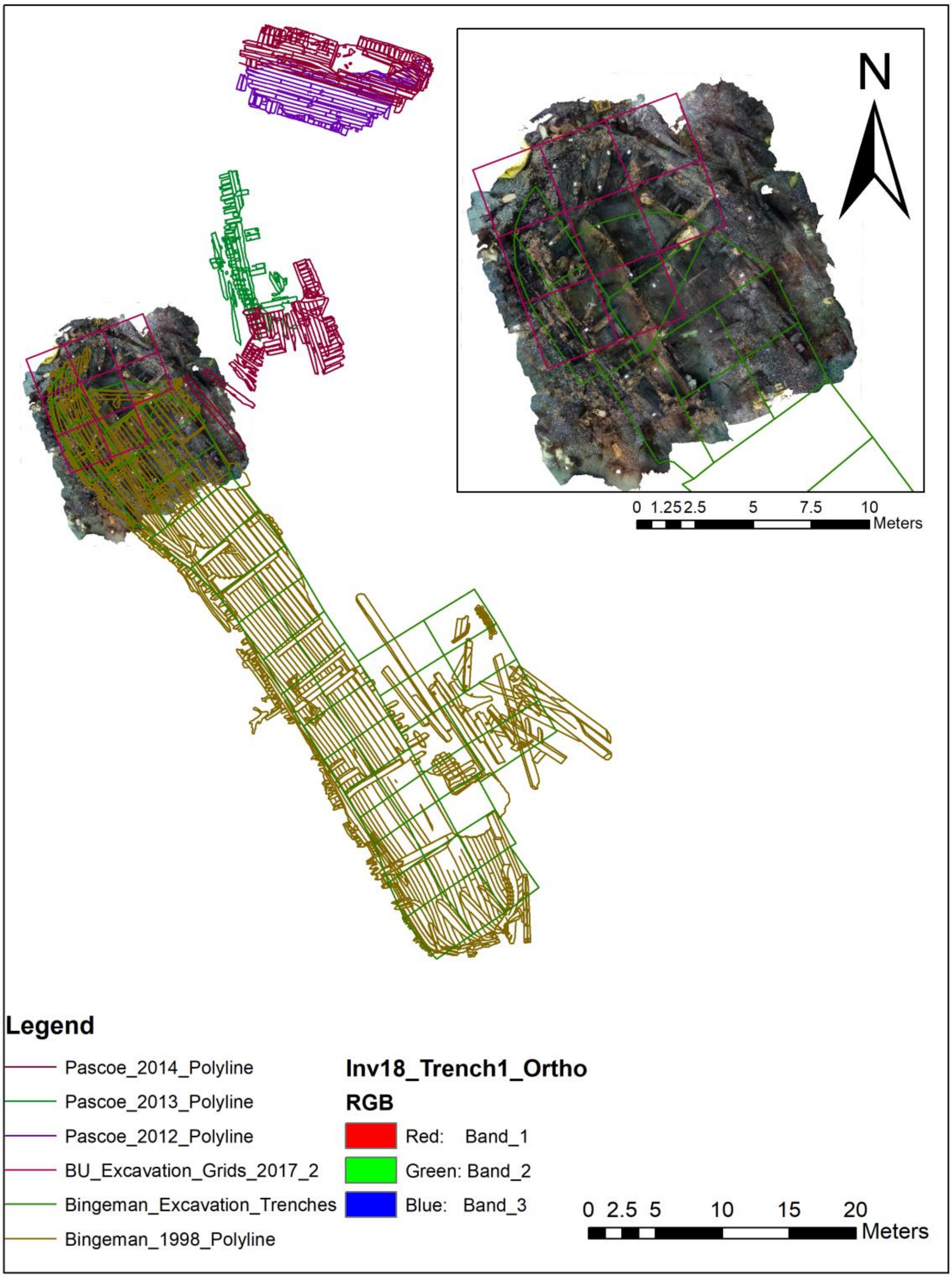

Figure 118. This map includes Bingeman's site plan and the excavation trenches from 1980 to 1990. The site has been re-digitised and a section added by Pascoe from 2012 to 2014. The recent excavation grids plotted from BU 2017 and projected for 2018. The author of this thesis made the map in Arc Map 10.5 ®.

7.6.5 Excavation of 2017 and 2018

The general outlay and main structural features from the *Invincible* wreck site are known due to previous work on site carried out by Bingeman from 1980 to 1991 (Bingeman 1981, 1985, 2010). However, the exact geospatial position of the site plans was unknown. The MBES surveys used to understand site dynamics have the most accurate positioning systems to locate parts of the wreck structure protruding from the seabed [387]. Therefore, the high-resolution MBES surveys (2015-2016), were essential to geo-reference and fully-integrate all the survey data on to the same temporal-GIS platform.

Firstly, the pre-disturbance (2015-2016) and the post-excavation (2017-2018) multi-image photogrammetry surveys were geo-referenced. Followed by Bingeman's site plans, which were required to be re-scaled to fit the ortho-rectified surveys of 2017 and 2018 (Figure 119).

The spatial inaccuracies created by our survey techniques have a direct impact on our understanding of the ship's structure in terms of scale, perspective and accuracy. Inevitably, site plans generated by hand drawings have a compound accumulated error while taking the measurement with a measuring tape and then plotting it on paper that is later merged with other surveys made by different people. Such spatial inaccuracies are considerably reduced by using multi-image photogrammetry, with fewer error variables and greater capture of detail. Creating an interpretative site plan from an ortho-rectified image will selectively highlight and classify structural remains (Figure 120).

Bingemans site plans confirm that he did not reach the keel at the bow section that would overlay with grids G3 and G8 for the 2017 and 2018 excavations carried out by BU. This area was excavated at the end of the 2017 season, revealing the forward mast step, which was recorded in high-resolution during 2018 (Figure 122 (A), and Figure 127).

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[387] Further discussed in Chapter III (Section 3.3.1.1).

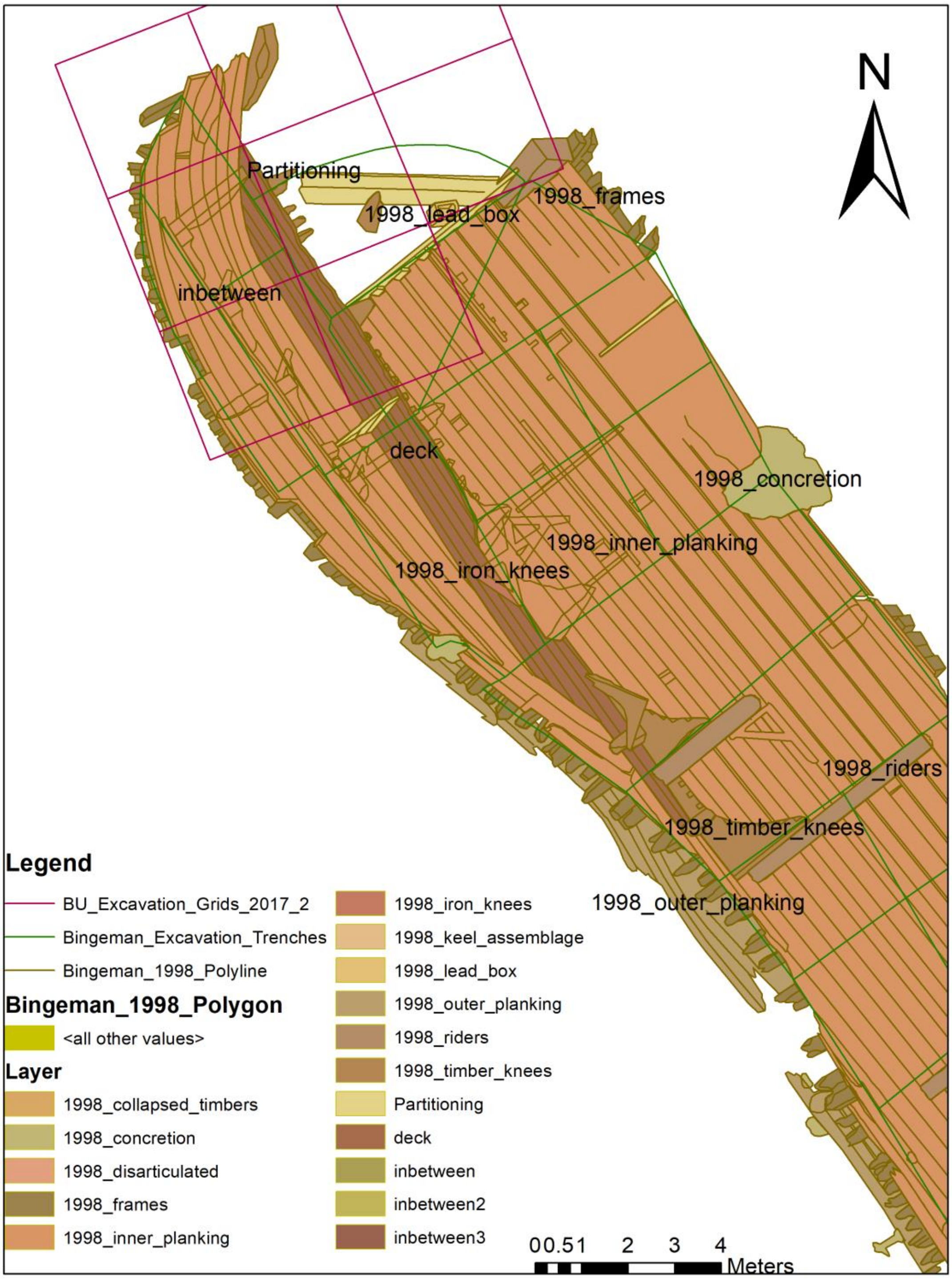

Figure 119. Bingeman's 1990 site plan re-digitised and colour coded by PAS in Site Recorder 4®. The author of this thesis made the map in Arc Map 10.5 ®.

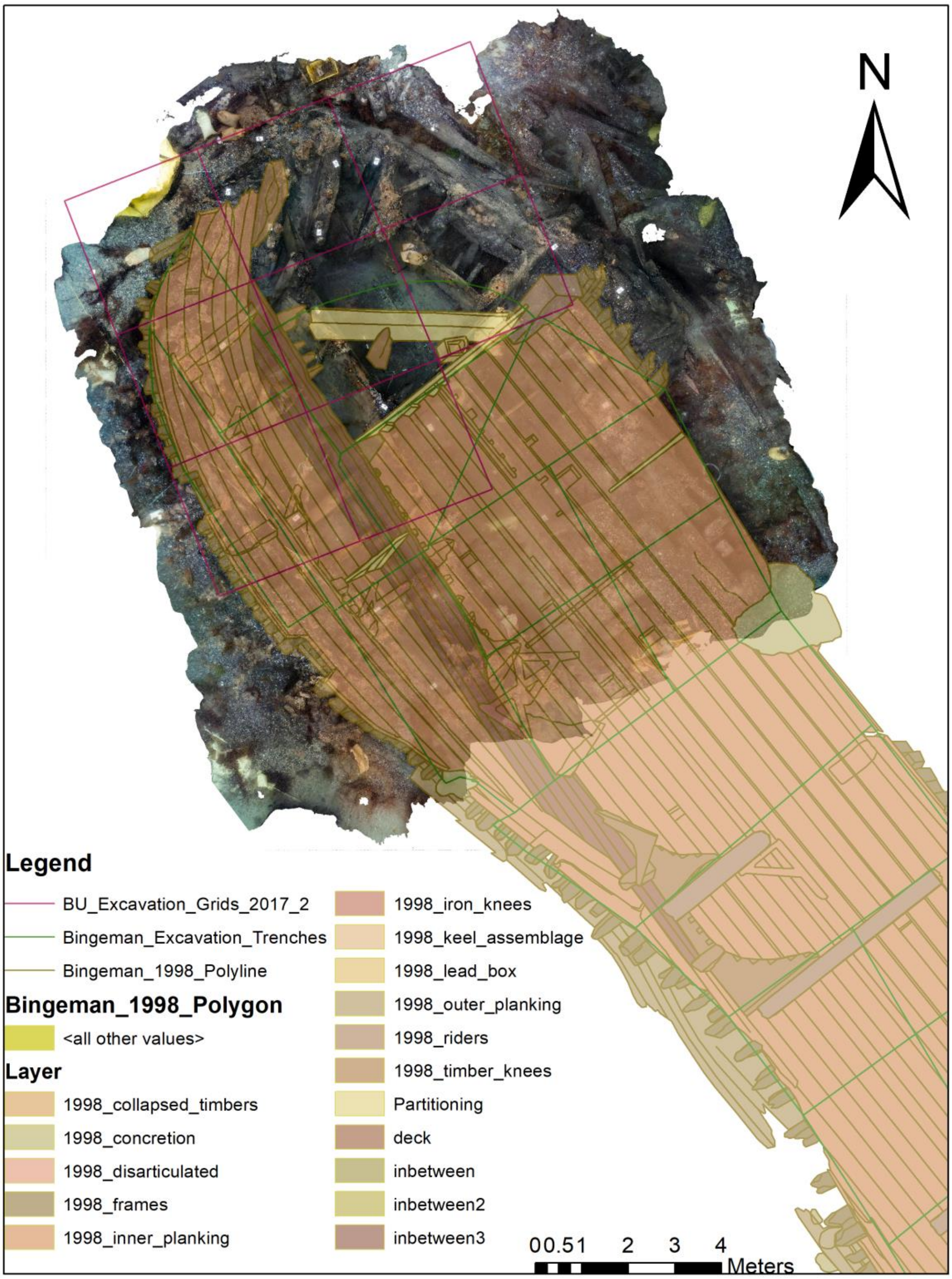

Figure 120. Orthophoto from 2017 with a re-digitised Bingeman's site plan overlaid. The author of this thesis made the map in Arc Map 10.5 ®.

7.6.5.1 The Bow, Portside Area

During the pre-disturbance surveys carried out from 2013 to 2017, the bow area of the wreck was designated as Area 1. During the 2018 excavation, the same area was renamed as Trench 1, to distinguish it from Trench 2.

The bow section consists of the port side of a coherent wreck structure, presenting a longitudinal cross-section of the *Invincible* that includes the keel, hold, orlop-deck and gun-deck (Figure 123 and Figure 124). The structure has a clear and abrupt disruption where the timbers were exposed to environmental erosion.

The hold of the wreck has floor timbers, and inner ceiling planking in exceptional condition, up to the supporting beams for the orlop deck (Figure 124 and Figure 125). As the hull curves following the stem (following the apron), a series of breast-hooks are found reinforcing the structure. Pine partitioning was found across the hull, to separate storage compartments for the ship.

The orlop-deck is supported by a series of main crossbeams and half beams placed transversally. In-between these main crossbeams, a carling is placed longitudinally, with several notches that would fit smaller crossbeams to support the orlop-deck. Flush laid pine planks make the orlop deck, from which rising knees are bolted to the side of the ship and run up to the main crossbeams of the gun-deck. To support the gun-deck a series mains beams, lodging knees and half-beams are placed (illustrated by Adams in Bingeman (2010:51–52) (Figure 122 (B)). To support the gun deck a series of iron knees, covered in pine cladding, are butted against the raising knees and main crossbeams.

The starboard side had collapsed and been scattered to the north by the effect of the prevailing wind and wave direction (Quinn et al. 1998) (Figure 112 (F)). The bow is disarticulated towards the stem that is scattered to the North-Northwest of the site (Figure 121 (A) and (B)). The disarticulated timbers need further excavation to reveal the full extent of this section as well as the lower part of the starboard side that could be buried beneath the sand to the Northwest of the site. The excavation in 2018 uncovered the keel following toward the stern until a point where it was broken off (Figure 121 (B)) and continues into Trench 2. In 2019, the excavation intends to connect both trenches to understand how the bow section broke off.

The aft section on *Invincible* is similar to the 74-gun ships illustrated by Boudriot (1973:103) (Figure 122 (A)). The coloured section represents the timbers that have been recorded except for the stemson, although this area still requires further exposure to classify some of the timbers. Adams sketch from 1983 in Bingeman (2010:52) illustrates reconstruction of how a storage room would be assembled, astern to the section that was excavated in 2017 (Figure 123). Both these sections show similarities, allowing the identification of structural features.

The rapid deposition of sediment at the bow section of the wreck allowed preservation of the inner structure of the port side from physical, chemical and biological decay. The remarkable degree of preservation is such that on the inner ceiling planking several carpenter's marks are found with roman numerals (Figure 126). The meaning of these woodcarvings needs to be analysed further to understand their relationship with the remaining structure.

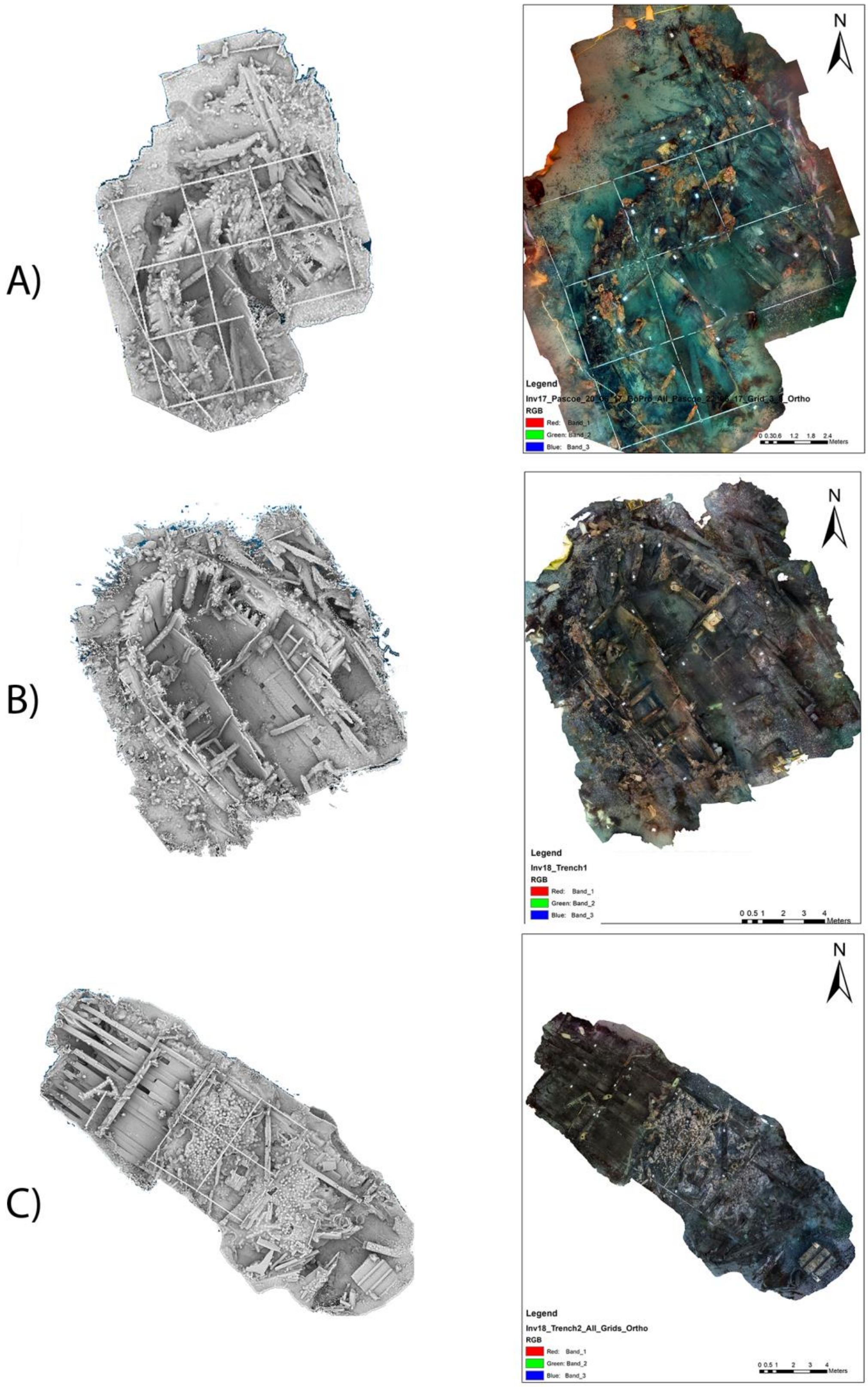

Figure 121. This figure presents the post-excavation dense cloud models with PCV-plugin for Cloud Compare ® and the orthophoto. A) Area 1 2017, B) Area 1 or Trench 1 2018, and C) Trench 2 2018. The 3D model was created in Agisoft Metashape Pro v1.5 ®. The author of this thesis made the figure.

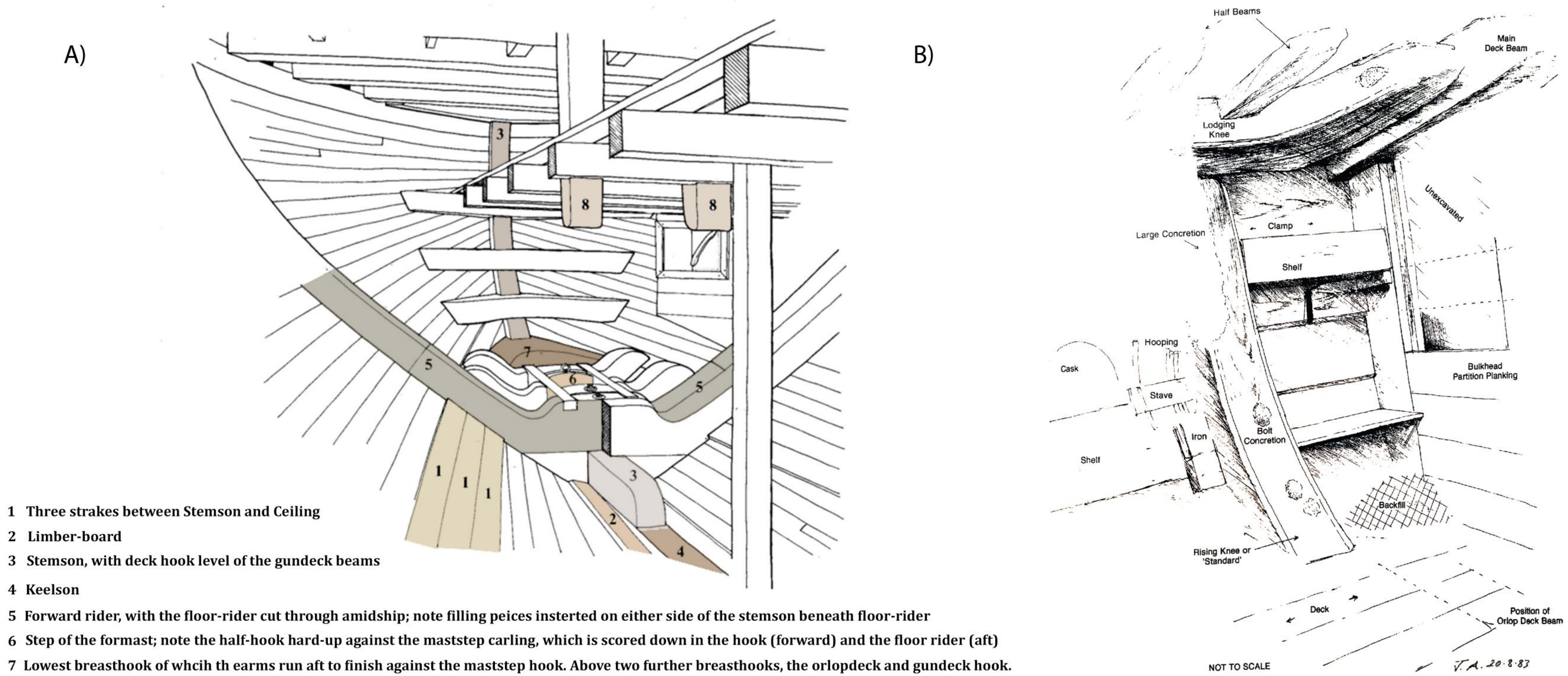

Figure 122. A) The figure shows the hull construction of the bow section of a 74-gun ship, based on Boudriot (Boudriot 1973:103)**, and colour coded by the author. B) Sketch by Adams of a storeroom on *Invincible* represented on an even keel** (Bingeman 2010:52)**. The author of this thesis made the figure.**

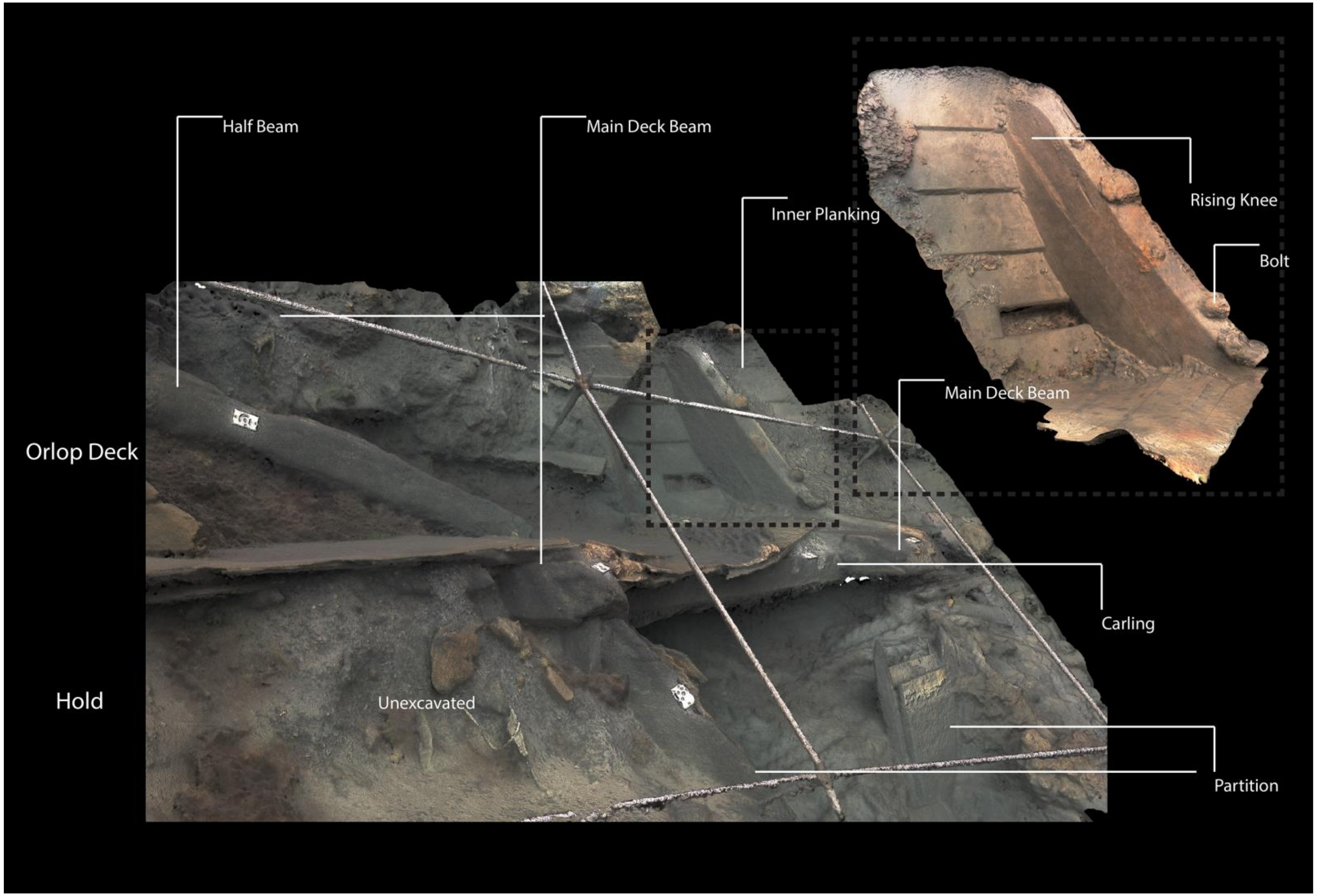

Figure 123. The figure shows some of the ship construction details found on *Invincible,* in Area 1 on the bow section. The image is based on a high-resolution photogrammetry survey done in 2017 and post-processing on 3Dsmax®. The author of this thesis made the figure.

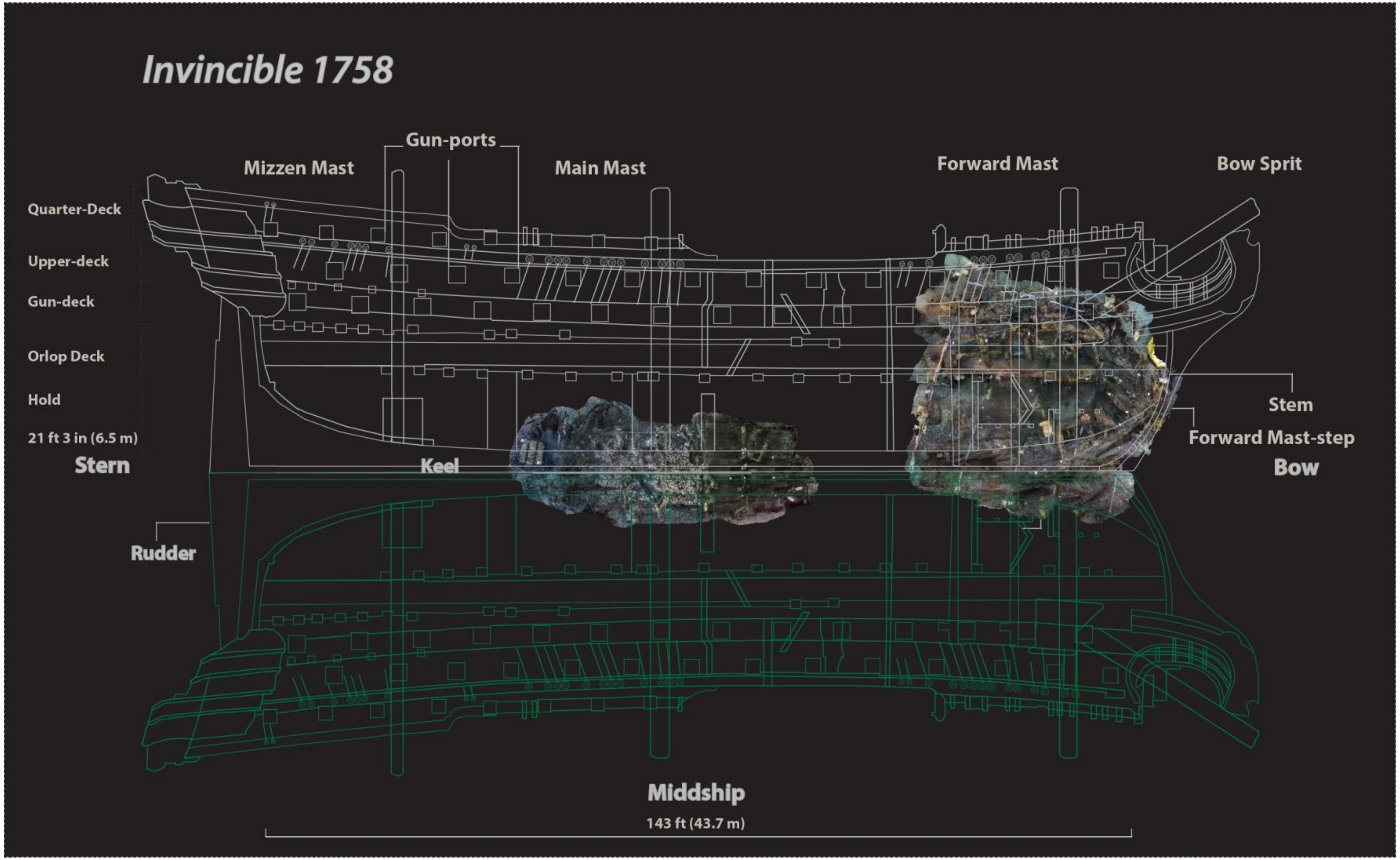

Figure 124 The image was rendered on 3dsMax® based on a photogrammetry model made on Agisoft Metashape Pro v1.5 ®. The image shows an interpretation of the shipboard associations of Trench 1 (Area 1), and Trench 2 surveyed in 2018, overlying a lines plan of Invincible. The author of this thesis made the figure.

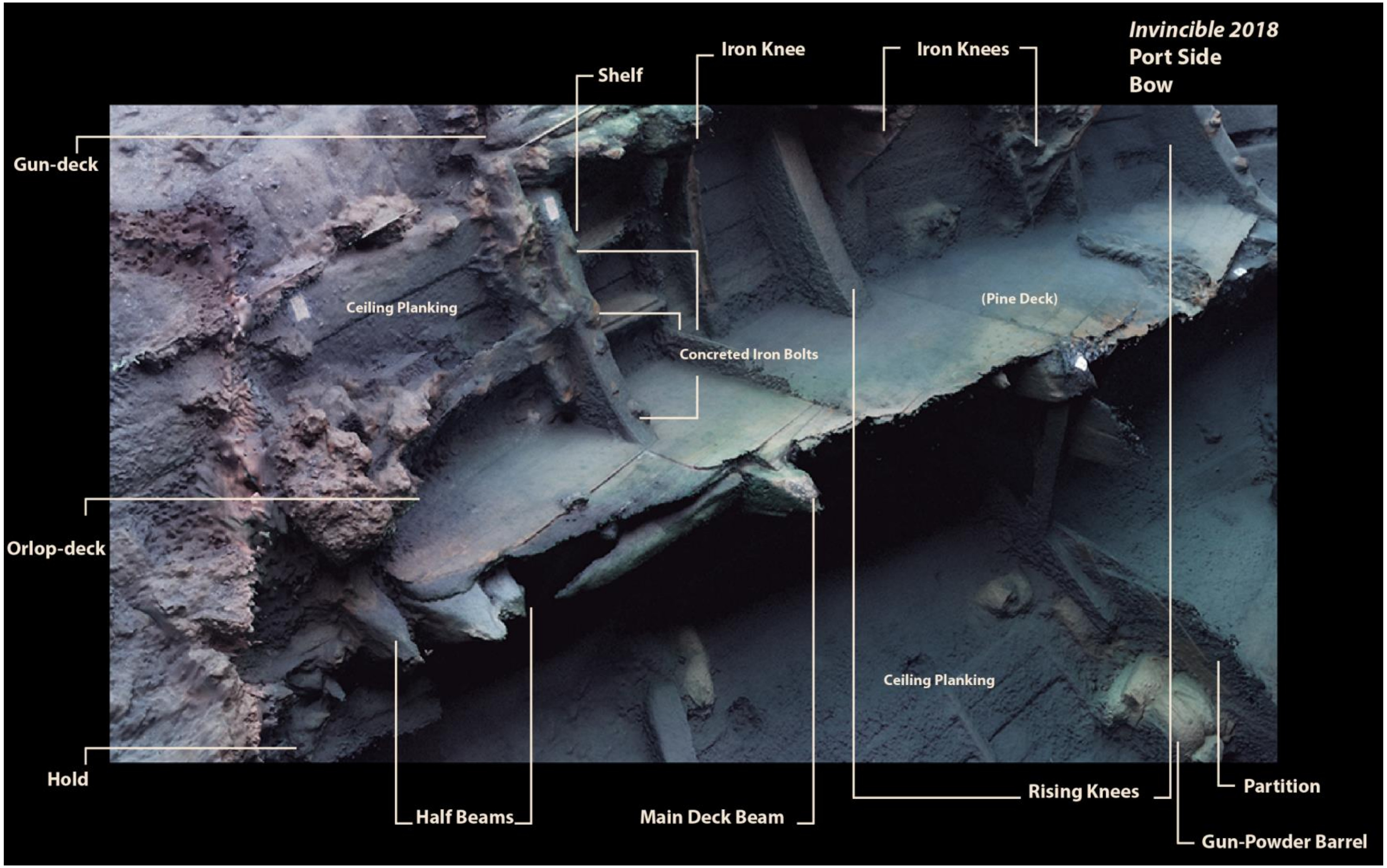

Figure 125. The image was rendered on 3dsMax® based on a photogrammetry model made on Agisoft Metashape Pro v1.5 ®. The image shows structural features found in Trench 1 (Area 1), surveyed in 2018. The author of this thesis made the figure.

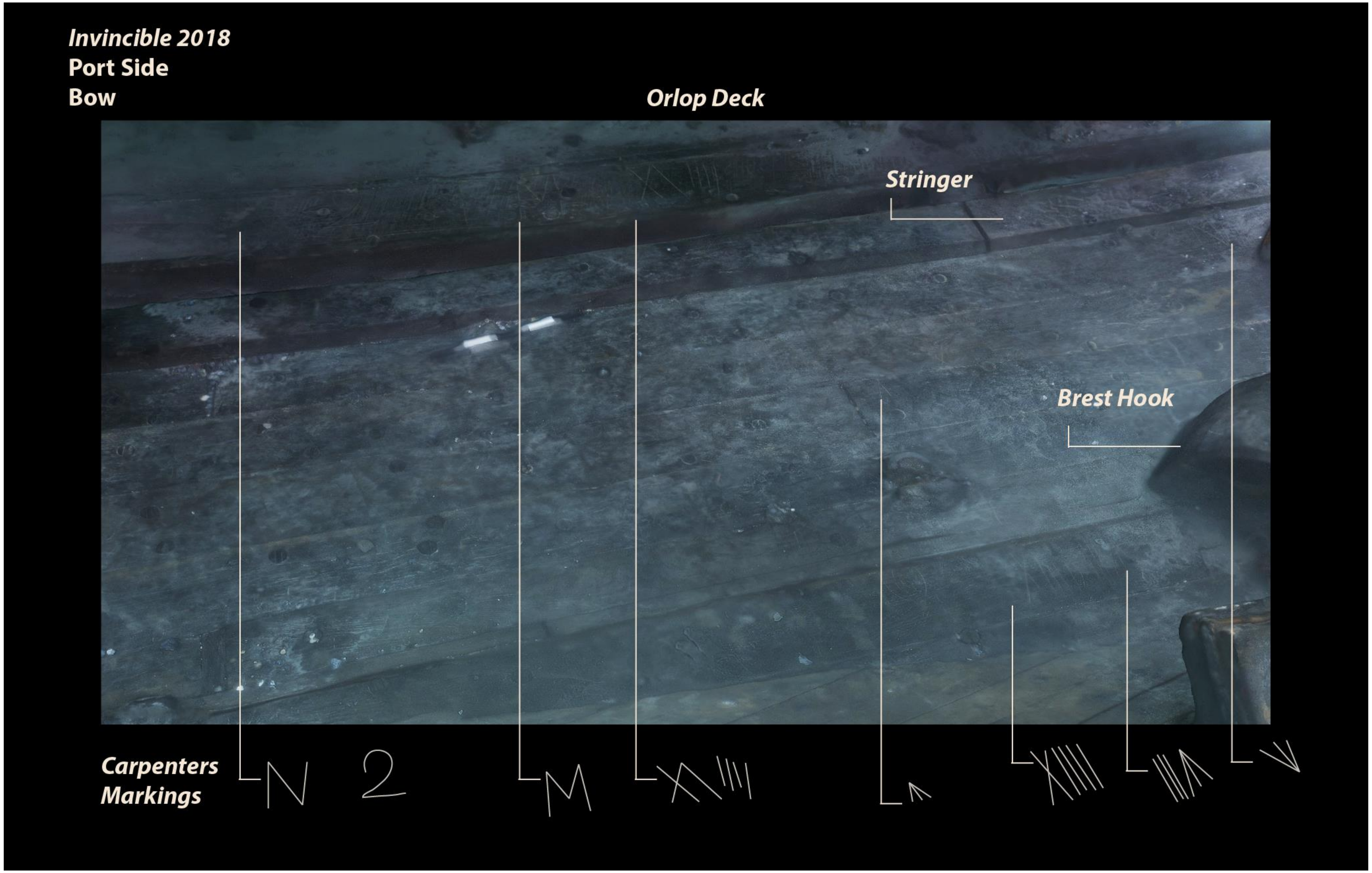

Figure 126. The image was rendered on 3dsMax® based on a photogrammetry model made on Agisoft Metashape Pro v1.5 ®. The image shows a close-up detail of carpenter's marks in Trench 1 (Area 1), surveyed in 2018. The author of this thesis made the figure.

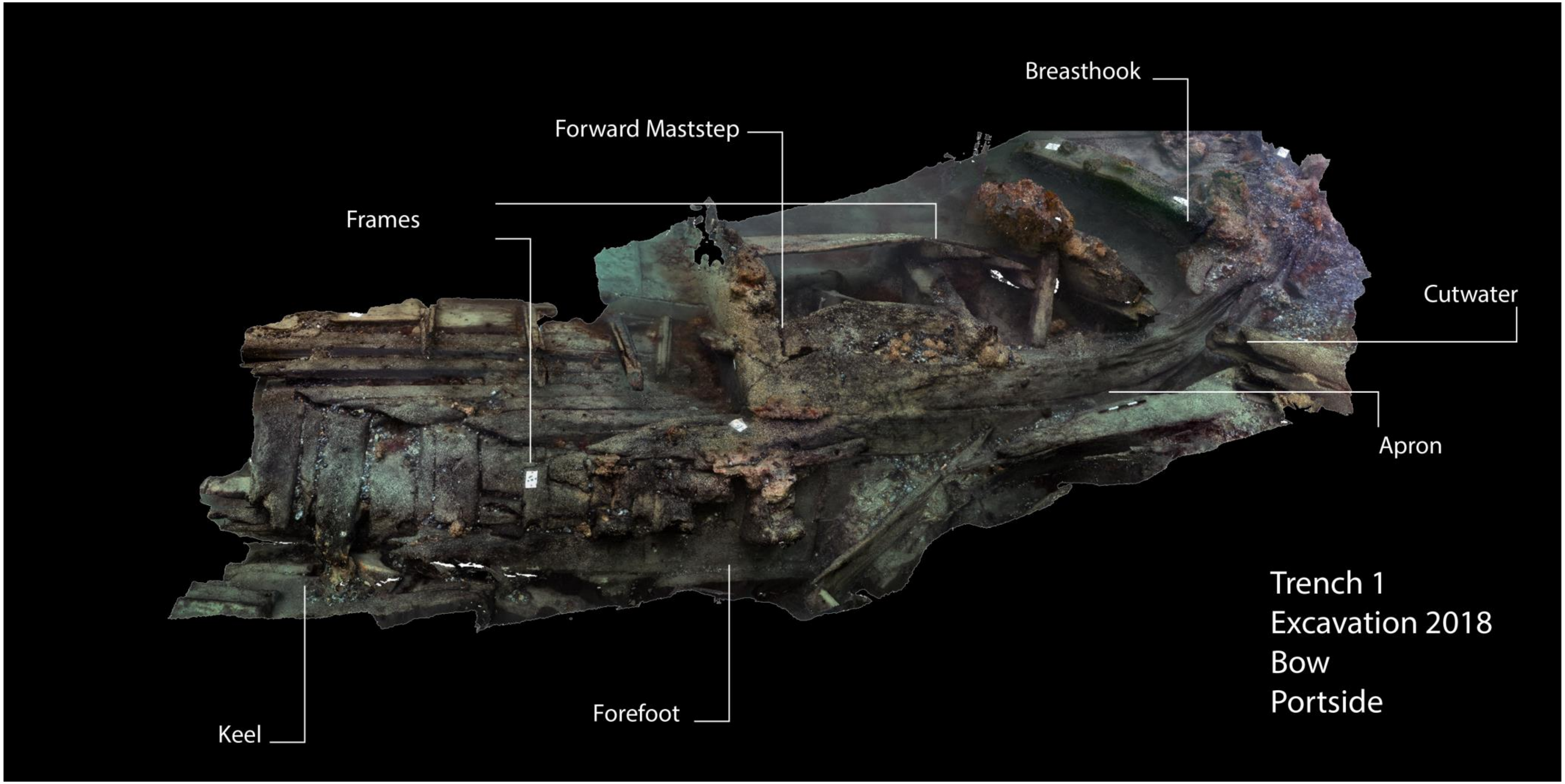

Figure 127. The image was rendered on 3dsMax® based on a photogrammetry model made on Agisoft Metashape Pro v1.5 ®. The image shows a close-up detailed model of the Keel, Keelson, and Stem in Trench 1 (Area 1), surveyed in 2018. The author of this thesis made the figure.

7.6.5.2 The Shot-locker and Limber-channel. Amidships Area.

The excavation in 2018 intended to uncover from the bow section (Trench 1 or Area 1), following the keel towards the stern to understand both portside and starboard side at the lower part of the ship. However, the keel that was uncovered in Trench 1 was evidently broken off.

In this light, a second area that targeted a previously unexcavated part of the wreck was opened. Trench 2 was placed on top of a cannonball mound that, as the excavation progressed, revealed the shot-locker of the ship (Figure 121 (C)).

The shot locker was clearly delimited by floor riders that are placed transversally across the bottom of the ship (Figs. 130 131, and 132). The floor rider (Hook) is placed on top of the floor, and right through the middle of the structure runs a limber-channel[388], with several limber boards [389], that provide access under the floor rider (Boudriot 1975:102)**.** The limber boards are labelled with L and S, standing for larboard[390] and starboard. The floor timbers are laid flush against the underlying frames, or first futtock. A large iron knee is on top of the floor timbers that would have collapsed from the gun-deck. Lead pipe was found, possibly part of the bilge pump that failed during the wrecking event and could not clear the water from the hull. The keelson and keel are underneath the limber-channel (Figure 129), although the methods of assembling the floor timbers to the rising-wood are still to be recorded in future excavations.

In sum, Trench 2 is clearly part of the amidships section with the best part of floor timber preserved from *Invincible,* of both starboard and port side.

The shot-locker would be a heavy part of the cargo on a warship, hence the preference to keep it low to the centre of gravity for stability during navigation. The orientation of the keel in Trench 2 could be the original position where *invincible* ran aground, and during the post-deposition process, the keel broke of separating the bow section.

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[388]A channel is cut in the outer face of the hull timbers, joining the spaces, so that the water can run away between them. The position of the limber-boards immediately above the limber passages makes it possible to clean them out.

[389] Limber boards can be lifted up in sections, since between station of the fore-body and station of the after-body it is not nailed down.

[390] In 1756, the port side would have been called the larboard side of the vessel. The confusion with the word starboard finally led to the adoption of the word port in its stead. The Admiralty Order of 1844 forbade the use of larboard (Boudriot 1975:31).

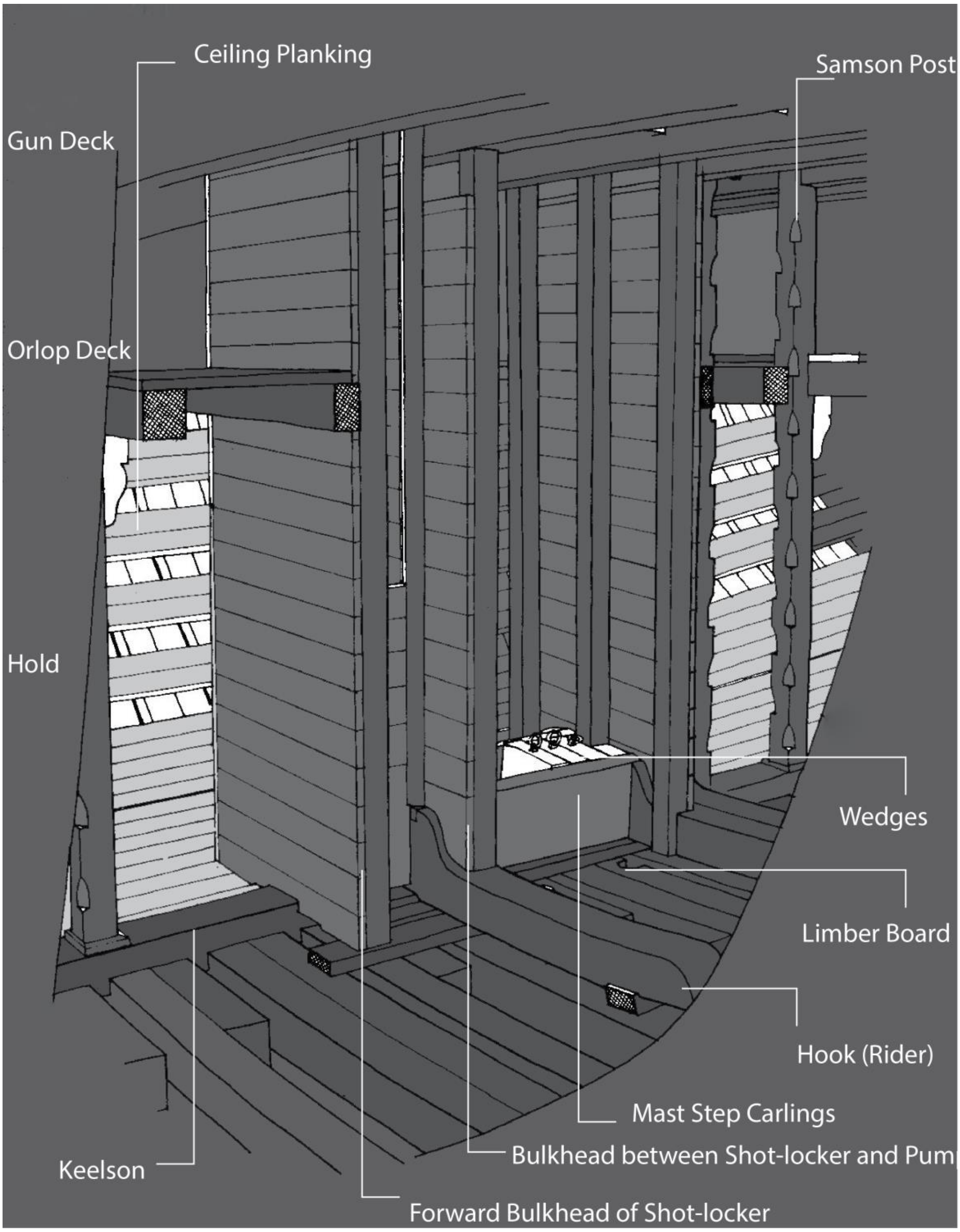

Figure 128. The drawing is based on Boudriot (1975:102), it has been modified, colour coded and annotated by the author of this thesis to highlight construction features found on *Invincible.* The author of this thesis made the figure

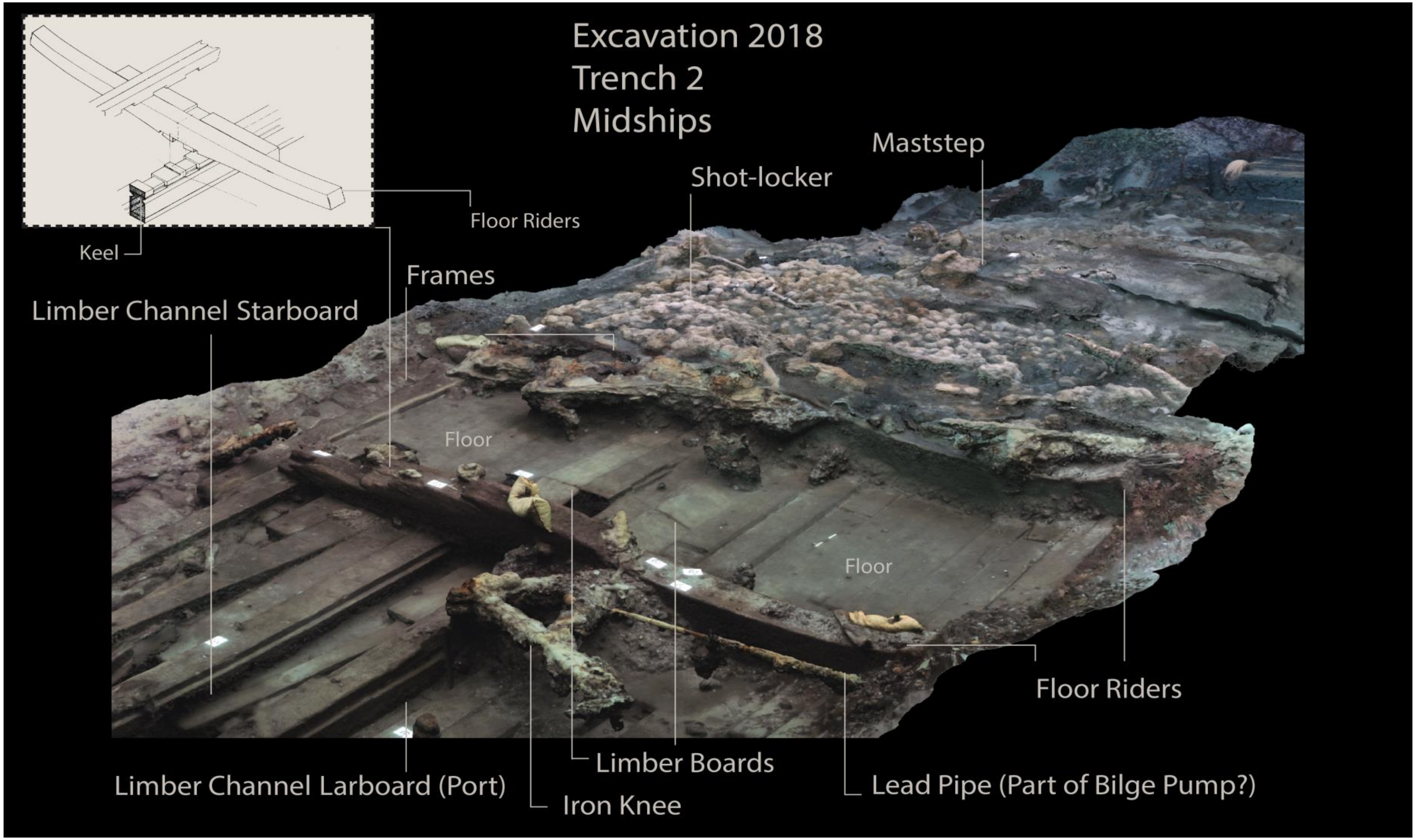

Figure 129. The figure shows Trench 2 and structural elements explained. The image was rendered on 3dsMax® based on a photogrammetry model made on Agisoft Metashape Pro v1.5 ®. The author of this thesis made the figure.

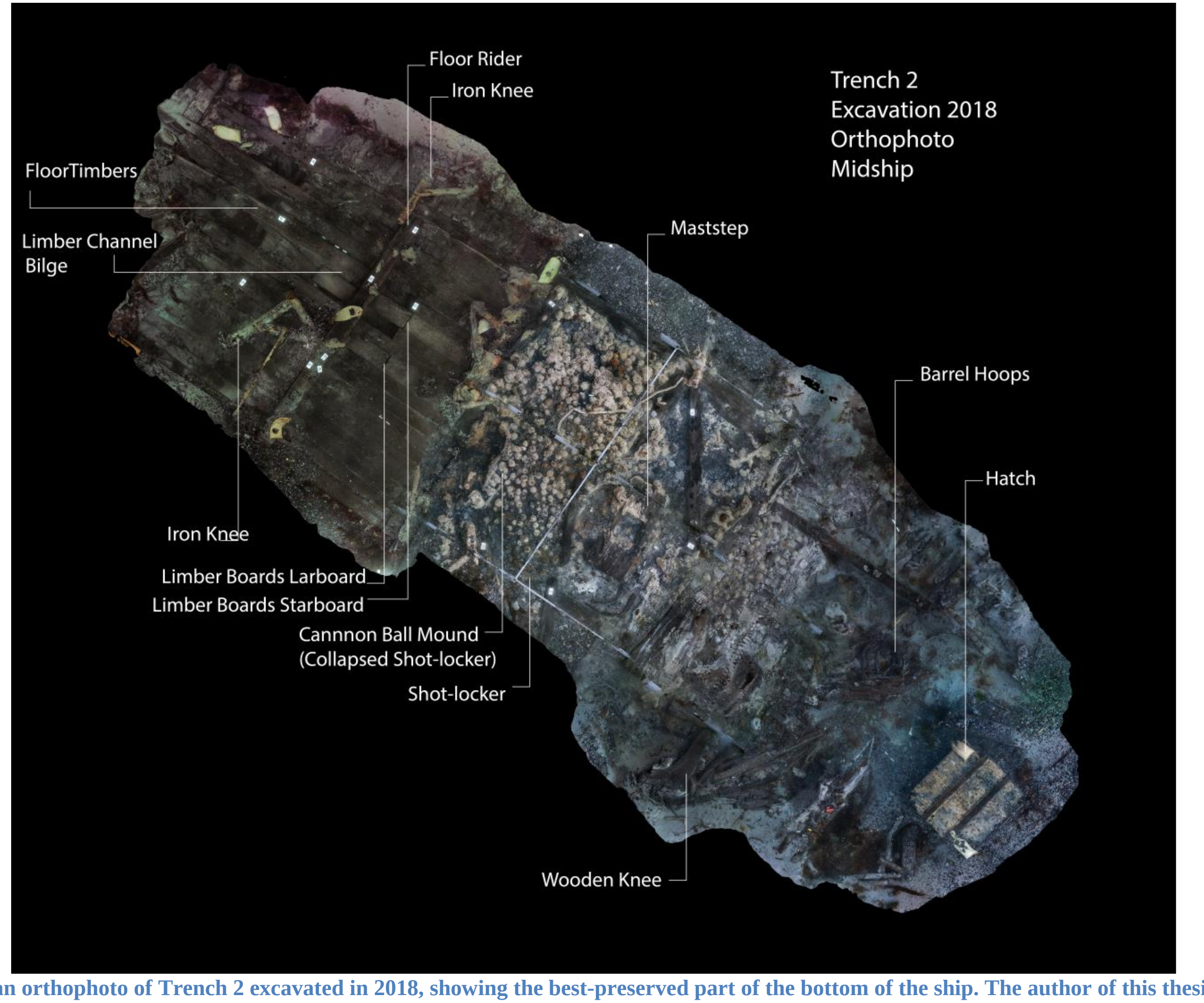

Figure 130. This is an orthophoto of Trench 2 excavated in 2018, showing the best-preserved part of the bottom of the ship. The author of this thesis made the figure.

7.6.6 Artefact Distribution

The distribution of artefacts within the ship's structure reveals the use of space within the hull, but also, artefact mobility is an indicator of post-depositional processes, *extracting filters* and *scrambling factors.* However, further analysis is still required to understand this process in the previously unexcavated areas with undisturbed archaeological contexts.

An extensive collection of the artefacts excavated by Bingeman (1980-1991) is currently on exhibition at The Historic Dockyard, Chatham. The Maritime Archaeology Trust (MAT) created an online database from this collection in 2008, that was initially available on the *Invincible* Site Viewer (MAT 2008). However, this site is currently migrating platforms and is temporally unavailable[391].

The artefacts recovered in 2017 and 2018 carried out by BU-MAST, are currently in conservation treatment. The Royal Navy Museum in Portsmouth will host a permanent exhibition for the recovered artefacts after the project has concluded. After the 2019 excavation, the virtual tour (Pascoe Archaeology 2018b) will be updated with the information for the excavation (2017-2018).

The historical source mentioned that during the wrecking of *Invincible*, the bow was the first section to be completely submerged underwater (ADM 1758; Bingeman 2010; Lavery 1988; PRO ADM 1/5297 1758a; PRO Adm 51/471 1758). As no contemporary salvage was possible, this area had great potential for artefact preservation that would help understand the use of space on board *Invincible*. In addition, Bingeman had left a part of the bow unexcavated. One of the completely unexcavated areas was Grid 3 (G3), which provided an excellent opportunity to explain how artefacts were collected at the bottom of the hull and rapidly covered by sediments (Figure 131). The rigging blocks found in G3 show a semi-closed system at the bottom of the hull of *Invincible*, close to the keel. The good state of preservation reveals that this area was filled in shortly after the wreck. However, the top single block is witness to the sediment migration (<200mm) that has temporarily exposed it, allowing the shipworm to eat the wood (Figure 132 and Figure 133). Other examples of single, fiddle and clew block have been

[391] Follow the link for Invincible site viewer: (http://www.maritimearchaeologytrust.org/mapguide/maps/invincible/main.php)

previously found by Bingeman, however, they were not recorded *in situ* (2010:77, 84, 89–90)[392]. During the 2018 excavation, several more pulley blocks were recovered following the scattered starboard side close to the keel. Some of these pulley blocks and dead eyes were part of the rigging, as they still had a rope going through the sheave.

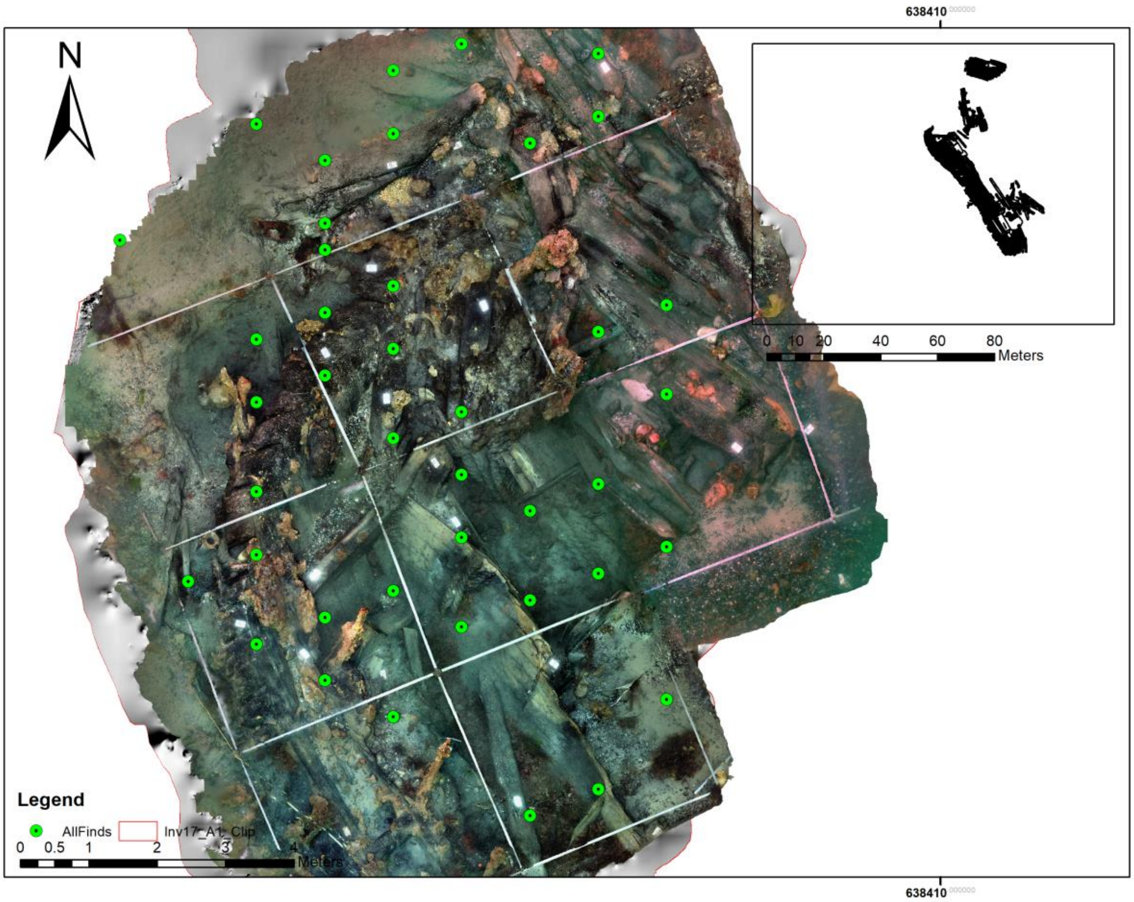

Figure 131. Preliminary artefact distribution from the 2017 excavation, by grids. The information was kindly provided by BI-MAS

392 Follow the link for a full animation with artefacts from the gunners stores https://vimeo.com/280616041. (Password Invincible1758).

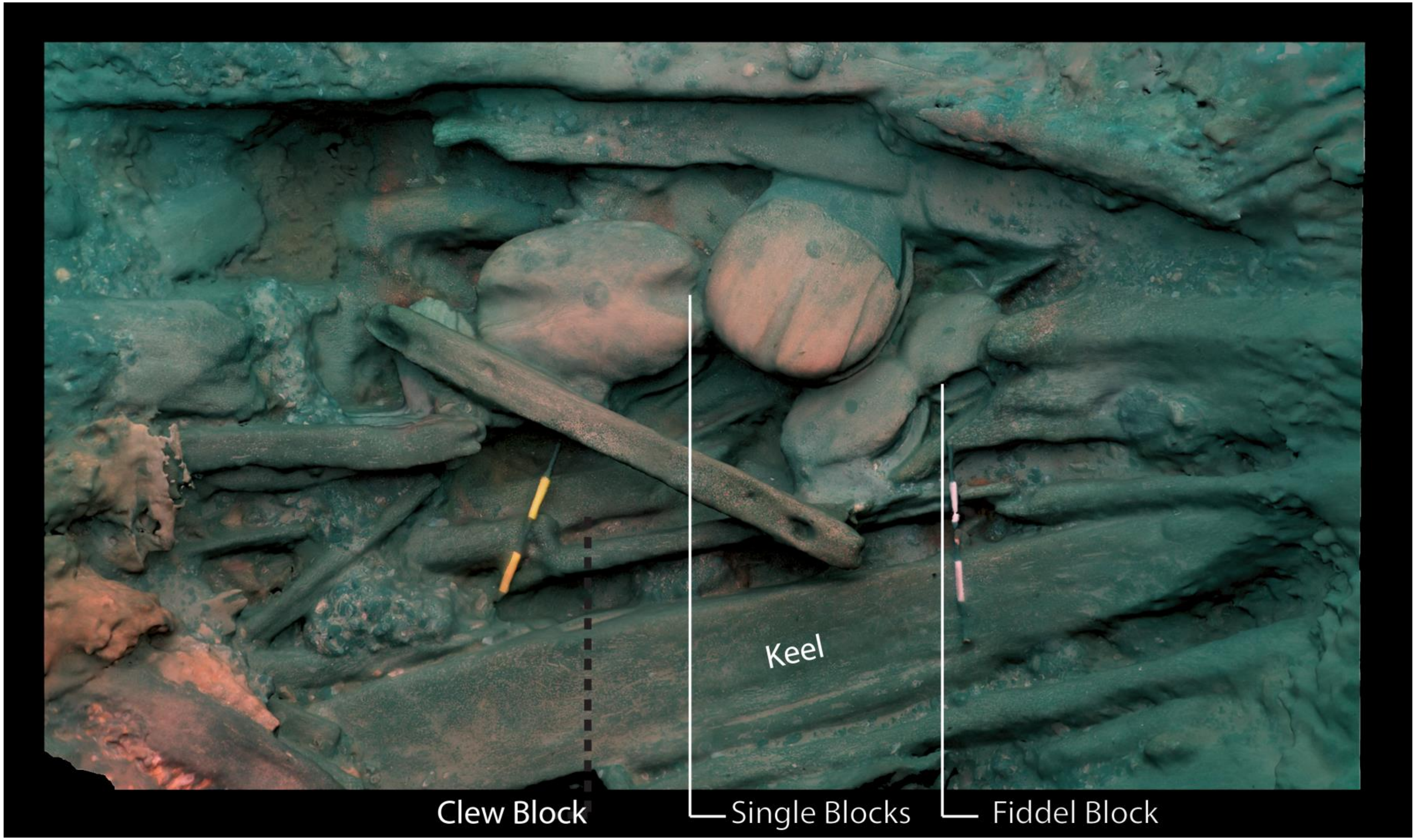

Figure 132. Close-up photogrammetry model of Grid 3 with rigging block in situ on 17/06/17. Image rendered in 3DsMax ®. The author of this thesis created image.

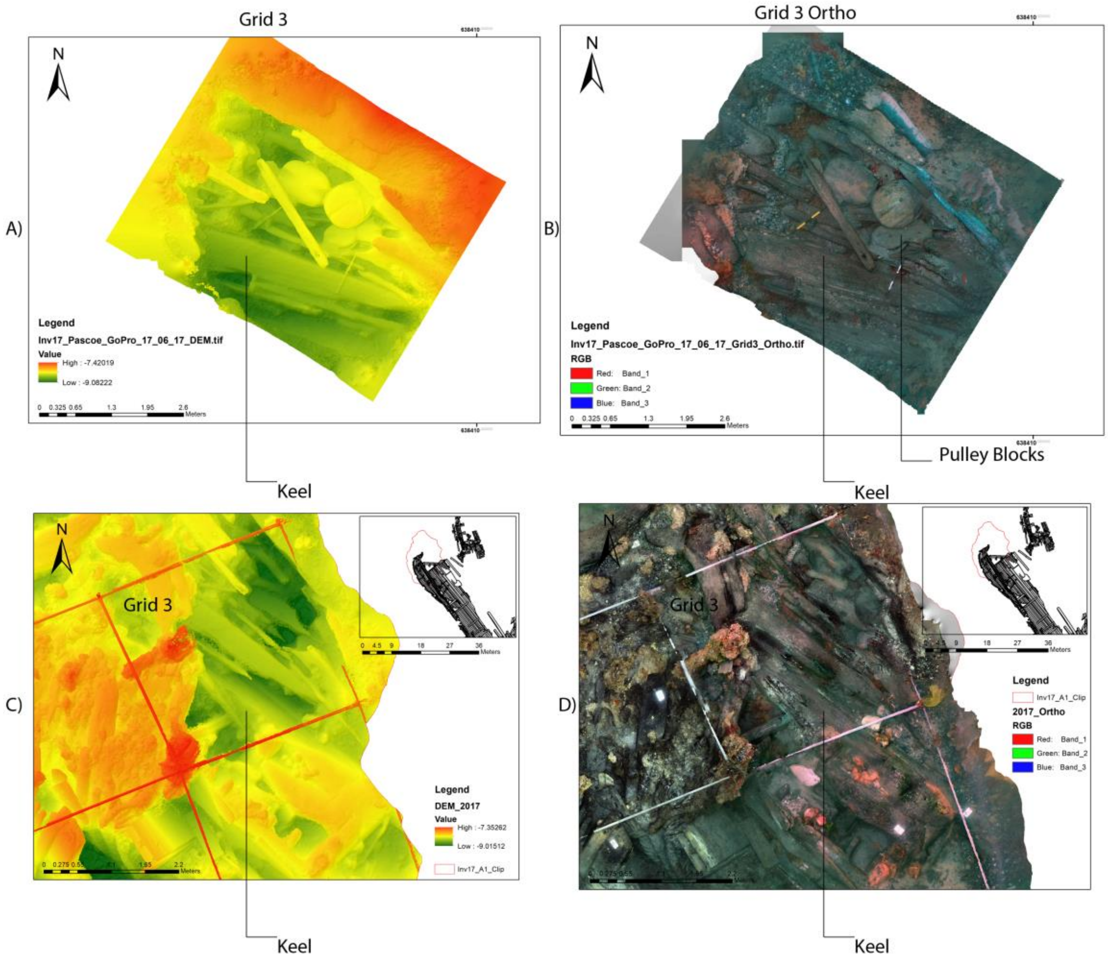

Figure 133. The first survey of Grid 3 with rigging blocks, made on 17/07/2017 showing: (a) DEM and orthophoto (b). The second survey of Grid 3 without rigging blocks, made on 22/07/2017 showing DEM (c) and orthophoto (d). The author of this thesis created an image in ArcMap 10.5®

7.7 Discussion

On a macro-scale, the MBES time-series demonstrates that the wreck is vulnerable to environmental erosion, mainly because of the migration of the Horse Tail sandbank in a southerly direction. The migration of this sandbank will transform the moderate-energy environment into a high-energy one. The northerly part of the site (Area 2) already bears witness to these effects, as the edge of the sandbank, marked by the – 6m CD contour line is less than 20 m away (Figure 134). When this sandbank finally uncovers the whole extent of the wreck, the environmental erosion will have an acute impact on the structural remains, deteriorating the coherent portside. Once the wreck is exposed the deterioration will eventually lead to having elements of the structure deteriorate or disappear, similar to the *Hazardous Prize* (see Chapter V). Without the protection of the sandbank, the *Invincible* will deteriorate exponentially due to storm and wave action, in a north and north-easterly direction (Quinn et al. 1998:133). The sediment migration of Dean Sand and Horse Tail is not as drastic as that observed in the Goodwin Sands. On wrecks such as *Rooswijk*[393] or *Stirling Castle* (Astley 2016:189), large and medium subaqueous dunes migrate at a rate of 50 to 60 metres per year. Nonetheless, the Eastern Solent is still highly dynamic and subject to strong tides that will continue to erode the site.

The *Invincible* presented a challenge for the vast amount of information collected on this fascinating wreck. The compilation and integration of over 35 years of previous work on site with the newly collected information brought to light the weaknesses and strengths of the data sets. The integrated methodology of this chapter included:

- Site plans, photographs, videos, dive logs, drawings and publications derived from Bingeman (Bingeman 1981, 1985, 2010) and archived by the Maritime Archaeological Trust[394] (MAT 2008).

[393] See chapter VI sections 6.4 and 6.6

[394] Formally known as the Hampshire and White Trust for Maritime Archaeology (HWTMA).

- Marine geophysical assessments (Quinn et al. 1998; Wessex Archaeology 2004b, 2015) and MBES data collection with the University of Southampton (2014, 2015 and 2016).
- Site plans, multi-image photogrammetric surveys from Pascoe (PAS 2015; PAS and Artas Media 2018; Pascoe 2013; Pascoe Archaeology 2018b) and Ortiz-Vázquez (2013).
- High-resolution surveys from the most recent excavations in 2017 and 2018 by Bournemouth University.

The diversity of techniques meant that there were different resolutions, coverage, accuracy, objectives and scales for each survey. However, this research managed to integrate them to present a 4D model of the site.
On a mesoscale, the high-resolution MBES time-series presented an effective method of monitoring sediment migration and locating archaeological features. It allowed for the covering of extensive areas, and geo-referencing of the rest of the data. However, it is important to recognise its limitations in terms of resolution and interpretation capabilities. The systematic multi-image photogrammetry time-series, on the other hand, presented an innovative and reliable survey technique to monitor change on the shipwreck. It was therefore through the combination of MBES with multi-image photogrammetry that new insights were gained at an intra-site level. The excavations of 2017 and 2018 produced key datasets and *in situ* observations that were the centre point to integrate all the past work on-site onto a temporal-GIS platform.

The *Invincible* has an extensive coherent structure that offers a window into mid-18th-century shipbuilding, maritime practices and the use of space on board a Royal Navy ship prepared for trans-Atlantic voyages. The *Invincible* presents a great comparative case study with the *Rooswijk,* which in contrast has no coherent structure. The few shipboard associations had to be deduced from analysing artefact distribution on a wreck[395]. Further analysis is required on *Invincible* to understand the distribution of the artefacts that will offer the next stage of intra-site level interpretation. This is a task for the future after the final season of excavation for the Invincible 1744 Project in 2019.

[395] See Chapter VI section 6.6.3.2 for further detail

The interpretation shown in 2D site plans and sketches allows the highlighting of specific features as well as the illustration of assemblages of artefacts. However, the 3D data produced for this project opens up a completely new analytical tool for post-excavation analysis. These 3D modelling techniques have created a digital archive of the wreck that makes it possible to dismantle retrospectively and display selected features to highlight them for identification. The integrated application of these techniques has never been applied before on a submerged shipwreck in British Waters, to the extent of having annual surveys that create a 4D model.

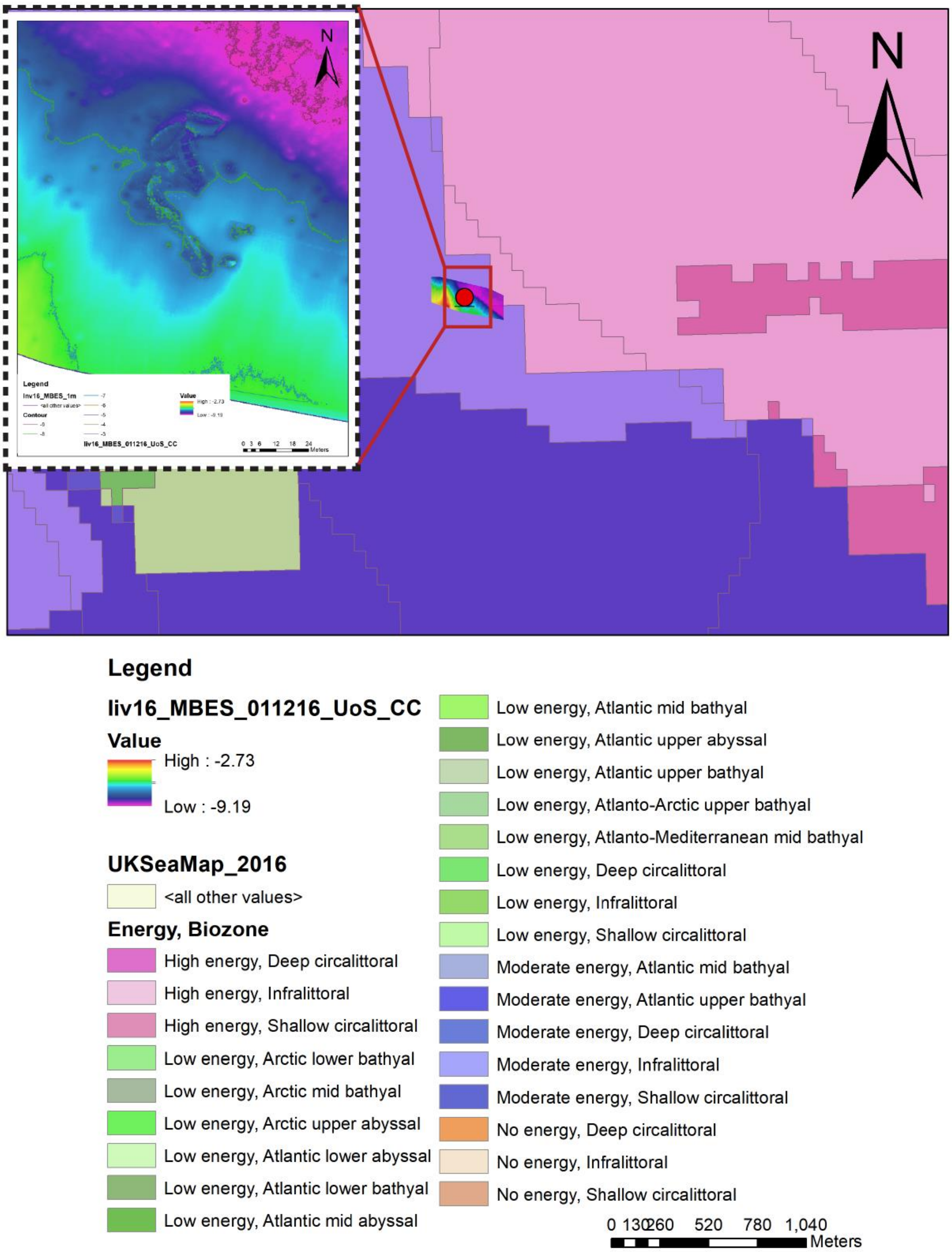

Figure 134. The map shows Energy levels according to EMODnet (2018), with the PW plotted according to HE (2018). UoS acquired the high-resolution MBES from 2016 and was processed by the author of this thesis, creating the figure in ArcMap 10.5®.

7.8 Conclusions

The wreck of the *Invincible* sits within a transitional environment moving from a moderate-energy (M1aM[396]) towards a high-energy environment (H1aM[397]). At present, the wreck has an extensive coherent portside structure, with many artefacts, and a scattered ordered starboard side with few artefacts. This transition will eventually have a major impact on the remaining wreck structure, making the *Invincible* vulnerable to environmental erosion. It has been proposed that destructive storm force, rather than the more acquiescent tidal forces acting on site, have dominated the formation of the wreck-site (Quinn et al. 1998). However, after the excavation of 2017 and 2018, it is possible to understand the true extent of its remains. The integrated methodology created a record of the structure, presenting not only a 2D top-down view but also a fully 3D structure including real depths in the structure.

Truly effective site management policies should promote comprehensive archaeological research methodologies that integrate information on a macro, meso and intra-site level. As demonstrated throughout the chapter, research should include several phases starting with pre-disturbance surveys and followed by systemic excavation. Without the excavation of 2017 and 2018, our knowledge of the site would still be limited to the skewed image of the site. The excavation revealed the true extent of the remains and this allows a more complete comprehension of the true impact of site dynamics on the underwater cultural heritage. The *Invincible* presents the best-preserved mid-18th-century warship in British Waters in which still has tremendous potential for future research. The detailed study of methods of timber assemblage will shed new light on French shipbuilding techniques and British re-fitting practises for Royal Navy vessels.

In sum, the integrated methodology of this project has recorded, measured and presented a 4D model of the changes to the wreck and the surrounding environment on macro, meso and intra-site scales; bridging the gap between large-scale remote sensing studies (EMODnet 2018; Fernández-Montblanc et al. 2016; Plets et al. 2013; Quinn et al. 1998) that model environmental dynamics and archaeological research at an intra-site level (Bingeman 1981, 1985, 2010; Pascoe 2013).

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[396] Table 21 in chapter IV section 4.3.
[397] Table 21 in chapter IV section 4.3.

7.8.1 Best Practice Recommendations for Further Research

- The MBES data used for a time-series should be the go-to process to guarantee the best quality, coverage and adequate resolution. This includes the inclusion and reanalysis of previously collected data. However, if it is newly collected data a survey should have a site-tailored methodology:
    - Correct processing of the data to, the natural environment and features (artefacts).
    - Select a colour scheme, similar to the one used by Fleidermaus®. Including DEM from photogrammetry – use the same colour scheme.
    - Display DEM with hillshading in the background to bring out the features more clearly (ESRI 2018a).

- Multi-image photogrammetry has become a standard recording tool in maritime archaeology for its practice and reliability, and it should be used whenever conditions allow. However, the implementation of MIP as an effective monitoring tool needs to consider the following points:

    - A ground control point network should be in place to guarantee scaled accuracy with DSM, also allowing the possibility of repeating surveys over the same area. The GCP should be geo-referenced with some reliable positioning device (USBL, total station or GNSS), or data set (MBES, LiDAR, Laser Scan). The depth should be relative to ODN or OD. It is important to be explicit on the ellipsoid and depth datum to create a reliable time-series and allow full integration with other datasets.

    - The data photographs for multiple image photogrammetry survey should be taken at the highest possible quality (preferably on a RAW format). This will have a direct effect on colour correction and white balancing for the images. The RAW format also allows post-processing and re-processing this data in the future when the hardware is more advanced, increasing the capabilities of the software[398].

[398] See section 3.3.3.3.

- Lastly, data integration of previous work on site is crucial for a comprehensive analysis (if available). However, critical analysis of methods and practice is necessary for their re-interpretation.

The excavation in 2019 will provide a much wider perspective on *Invincible's* structure, permitting this project to provide a better-informed interpretation of the site formation processes of the wreck. The disarticulation of the starboard side is still poorly understood on large extents of the wreck. The excavation planned for 2019 targeting the keel in the amidships area, will contribute substantially to understanding the full disarticulation of the wreck.

Lastly, a series of magnetic anomalies[399] still wait to be confirmed as six jettisoned guns[400] from *Invincible* during the wrecking process[401]. If so, this will add more information about the actual wrecking trajectory that *Invincible* experienced when she ran aground on Dean Sand. This could position her original wrecking spot somewhere different to where she is currently located, and explain part of the damage to the lower part of the hull.

[399] See Appendix II (B) *Invincible* for figures.

[400] *about 3 pm I threw overboard Six of the After Guns on the upper Deck , and began to start Beer and water as fast as possible: the ship struck several times pretty hard, but made no water till the Evening: About 7 in the Evening the Master Attendant and Pilot came on board: We immediately swayed up the fore yard, and mizzen Top Mast and set the Sails, and cut the Stream Cable and Haulers to endeavour to force her*' (PRO. ADM 1/5297 1758).

[401] This scheduled to happen during 2018, or the 2019 excavation lead by BU.

Chapter VIII. Discussion and Conclusions

This thesis set out to create an integrated methodology that addressed the dynamics of the shipwreck's environmental conditions at the macro, meso and intra-site level. In order to achieve this, the thesis started by producing higher quality archaeological results enabled by truly integrated methodologies that bridge the gap between macro, meso and intra-site level studies. Another main aim was to understand how can the integration of data from multiple temporal and spatial scales lead to an improved understanding of shipwreck site formation processes. To answer that question, it was necessary to review the tools and techniques used to survey shipwrecks and their environments, recognising the challenges of combining different resolution surveys and data sets to understand shipwreck site evolution.

To understand how shipwrecks have been recorded, Chapter II presented a critical overview of the pioneers of underwater exploration in the UK (Bevan 1996, 1999b; HampshireTelegraph 1835) and the origin of solid theoretical basis of site formation process in maritime archaeology (Dumas 1962; Gibbs 2006; Martin 2011; Muckelroy 1978a; Murphy 1997; O'Shea 2002; Stewart 1999; Ward et al. 1999). The literature review of theory and methods[402] explicitly highlighted the need to bridge the gap between large-scale analysis of the environment and intra-site studies of the wrecks.

This integrated methodology was foreshadowed by a critical analysis of theory, methods and practice in the generation of the archaeological record and the interpretation of site formation processes. The shipwreck classification based on environmental dynamics presented a general panorama of the UK and its Protected Wrecks. This thesis started by recognizing the lacunae in our understanding of shipwrecks and the impact of the surrounding environment, as well as the challenges of capturing a high-resolution record that would enable better-informed site interpretations. Thus, underlining a second question: If we can only quantify/describe to X level, how can we describe to Y level, and provide satisfactory future projections for sites?

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[402] Chapter III

To that end, certain methods will document underwater cultural heritage better than others, depending on the environmental conditions. Although the integration of different sources of information may improve the site's description, it allows for one technique to supplement the data where other techniques are limited. This was demonstrated with the case studies in Chapters V, VI and VII. Where MBES surveys are limited in resolution the multi-image photogrammetry provided complementary detailed data. Similarly, where multi-image photogrammetry is restricted due to environmental conditions, a USBL system (as employed on the *Rooswijk* 1740 project), allows for the tracking and positioning of artefacts.

The macro-scale analysis of Protected Wrecks in the UK presented in Chapter IV presented a new criterion to classify shipwrecks, which works in harmony with international standards. Chapter IV also highlights the importance of better cultural heritage care strategies that consider the complexity of marine environmental dynamics. This chapter also emphasises the importance of archaeological research at meso and intra-site scales, that includes high-resolution data-sets, such as presented in the case studies (*Hazardous, Rooswijk* and *Invincible*) [403].

Furthermore, this thesis successfully fulfilled the following objectives in chapters IV, V, VI and VII set out at the beginning:

1) To produce a temporal-geographical information system (t-GIS) that modelled the site formation processes on the selected shipwrecks (and their environments) with the combined historical, archaeological and remote sensing data.
2) To create geo-referenced maps that allowed comparing the short, mid and long-term site formation process.
3) To compare and integrate newly generated high-resolution datasets with *in situ* archaeological observations to produce better-informed interpretations.
4) To provide new information on localised environmental dynamics that enabled the identification of areas for future further research, as well as better cultural heritage care strategies.

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403 See Chapter V for *Hazardous,* Chapter VI *Rooswijk* and VII *Invincible*.

5) To demonstrate the potential of fully integrated methodologies on submerged shipwrecks using multiple-scalar analysis on specific case studies (*Hazardous*, *Rooswijk,* and *Invincible*).

8.1 Further Reflections on a Shipwreck Typology

As discussed in Chapter IV, typologies are essential for creating analogies between different archaeological sites or artefact assemblages by distinguishing their similarities and differences. These typologies are based on morphological, spatial and chronological (temporal) attributes (Adams and Adams 2007:19, 24, 240; Hill and Evans 1972). However, with a critical perspective, these typologies are also abstract concepts of reality and they can result in rigid frameworks that restrict multi-functional[404] or rapidly changing objects of study[405].

Considering the above, is it possible to classify shipwreck sites based on the wreck integrity and environmental conditions?

Muckelroy's scientific approach to this question, based on coastal geomorphology studies (King 1972), presented environmental attributes and their degree of significance regarding its impact on site (Muckelroy 1978a:162). However, Muckelroy did not have the technology to his disposal or data availability that we do nowadays. Muckelroy's idea of contextualising shipwrecks within environmental dynamics would have benefited from the macro-level analysis of seabed habitat maps that systematically classify the environments surrounding underwater culture heritage (EMODnet 2016, 2018; Populus et al. 2017).

The shipwreck classification presented in thesis re-enforces the need for multiple-scales of analysis. The macro-scale environmental classification based on high, moderate and low energy levels (EMODnet 2016, 2018; Populus et al. 2017) provides a suitable proxy to define regions. This classification includes energy levels that

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[404] E.g., a pulley bock can be classified as cargo or ship fittings simultaneously. Or a Pewter jug can be classified as domestic or cargo (see chapter VII on the *Rooswijk*)
[405] Rapidly changing landscapes that can be classified as either as moderate or high energy levels environments.

consider multiple variables such as depth, wave exposure (fetch), tidal currents, fetch, seabed topography and substratum.

However, a closer and critical examination on a meso and intra-site level, as demonstrated for the *Rooswijk* and *Invincible*, demonstrates that the resolution of this environmental classification is insufficient to account for local dynamics. The site dynamics of the *Rooswijk* presented a much more complex environment than previously thought. The real seabed migration pattern was revealed by the high-resolution MBES time-lapse survey. The wrecks in the Goodwin Sands, in particular, require more in-depth studies to understand local patterns and dynamics, as also seen with the *Stirling Castle* (Astley 2016; Astley et al. n.d.), *Northumberland,* and *Restoration* (PAS 2017). The closer observation of environmental dynamics on *Invincible* demonstrated that the Dean Sand migration pattern, in a southerly direction, is the critical factor that will determine a change in the energy levels of the environment, from moderate to high. However, the resolution of the EMODnet (EMODnet 2018) bathymetry does not clearly show the northerly limits of the sandbank. The *Invincible* site is currently classified as a moderate energy level, however, the mesoscale analysis of the wreck (Chapter VII) demonstrated that the wreck is undergoing a transitional phase that is moving towards a high-energy environment. This would have a visible impact on the shipwreck integrity and distribution of remains at an intra-site level.

In conclusion, the shipwreck classification presented here, moves forward from where Muckelroy started over 40 years ago and others have carried on in the same line (Ferrari 1994; Ferrari and Adams 1990; Gibbs 2006; Martin 2012; Oxley and Keith 2016; Stewart 1999; Ward et al. 1999), by integrating a broad range of data sets to model environmental dynamics. This classification system could prove a useful environmental proxy on a regional scale on other wreck sites across European seas, the Mediterranean and the Black Sea that also have EMODnet environmental classification coverage (Figure 135). The environmental energy level classification would provide a homogenous system for comparative site formation process studies on shipwrecks.

If this thesis had focused only on the meso and intra-site dynamics of each wreck, it would have resulted in a skewed panorama with a limited scope of the study. Analysing a single wreck within a broader environment is similar to trying to understand an entire ecosystem from a single tree. In other words, sometimes you cannot see the wood for the trees. However, shipwreck classification based on environmental dynamics puts things into perspective by understanding the level of vulnerability of each wreck as per their location, thus highlighting those that require immediate attention with targeted surveys, excavations, or both, in a more efficient way.

The *Hazardous, Rooswijk* and *Invincible* have successfully demonstrated how the quality of survey data collected, pre and post-excavation, has a direct impact on our capacity to model and interpret submerged archaeological sites. In the future, having more case studies to integrate to the environment-based shipwreck typology[406] will provide further insight into the capabilities of this system. Furthermore, having intra-site scale studies of these wrecks will offer higher resolution data sets to evaluate if the wreck is in a high, moderate or low energy environment as well as understand the state of preservation of the structure or artefacts.

The implication of the shipwreck classification presented here with a systematic approach to the wrecks' remains and their environment has a direct application for UCH care. However, as pointed out by Firth (Firth 2018) other anthropogenic factors also have a direct impact on wrecks that have interests, regulations and administrative systems that have a bearing on wrecks in the UK[407]. Even though a complete analysis of heritage management policies goes beyond the scope of this thesis, it is important to recognise the potential applications of the systematic research presented here.

[406] Table 20, Table 21 and Table 22.
[407] Overlapping interests and regulations conserning wrecks such as: fishing, public and environmental risl, commemoration, sea-use, nature conservation, ownership and recovery of wrecks, navigation safety and wreck removal/dispersal and recreation (Firth 2018:9).

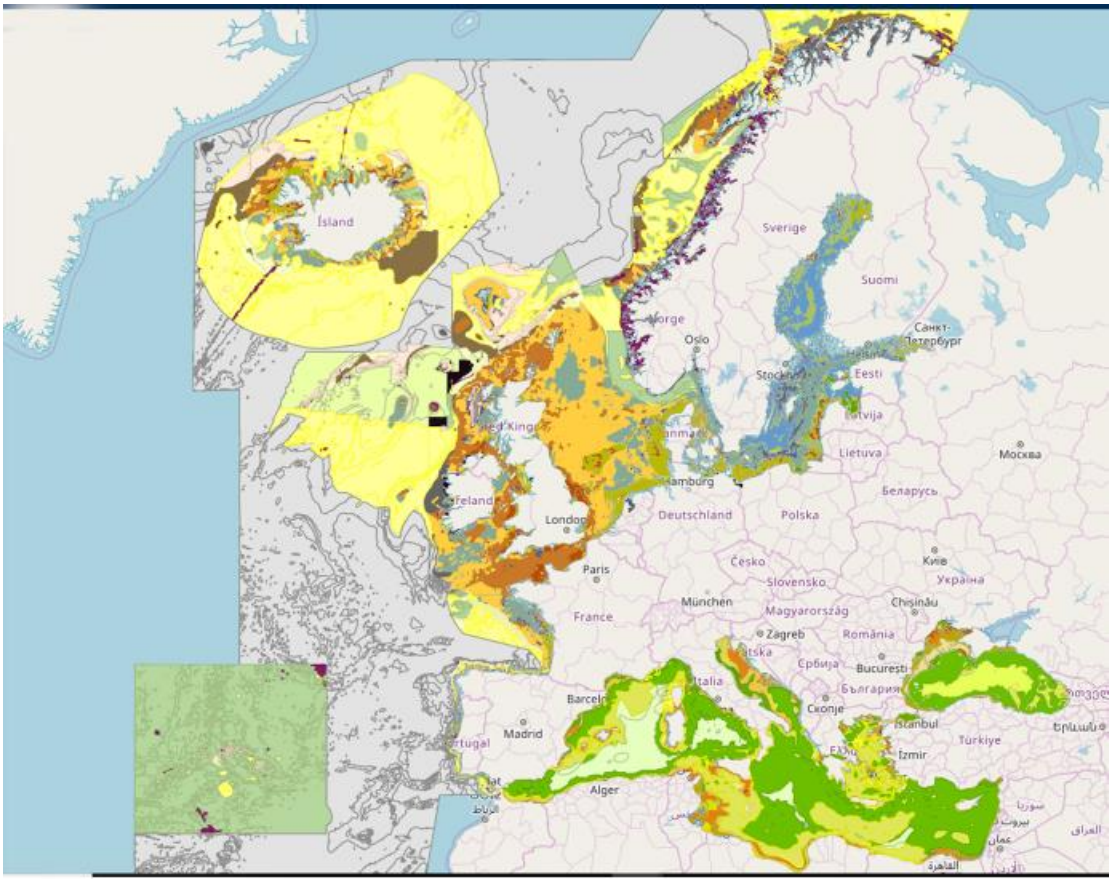

Figure 135. EMODnet Seabed Habitats coverage (EMODnet 2016, 2018; Populus et al. 2017).

8.2 Case studies

The main motivation behind the selection of the case studies was based on the possibility of carrying out different stages of fieldwork such as pre-disturbance surveys and excavations on a periodic basis on the same wrecks. This represented a unique opportunity to collect new data firsthand on three different wrecks that were being excavated during 2017 and 2018. Furthermore, the *Rooswijk* and *Invincible* projects both represent the most extensive underwater excavations in Britain for the past decade.

It is important to acknowledge that the practice of maritime archaeology by nature requires teamwork and that a multi-disciplinary synergy is essential to achieve results successfully. The challenges of working in British waters, the English Channel[408]

[408] The English Channel is also known as, *La Manche* in France or *Canal de la Mancha* in Spain.

(Eastern Solent and Bracklesham Bay) and the Goodwin Sands required extensive teams to carry out the fieldwork. Luckily, the *Hazardous, Rooswijk* and *Invincible* projects where all open to ideas of methods of recording the wrecks' and their artefacts. Otherwise, the development of this thesis would have been impossible to carry out. This rare opportunity, allowed to present a new 4D multiple-scale analysis of each shipwreck, moving from the macro to the intra-site scale, with the objective of providing new archaeological interpretations.

The development of the case studies presented in this thesis set out to answer critical questions. Does our understanding of the site formation processes of a wreck improve with pre- and post-disturbance surveys? Moreover, in what way does recording with new technologies enhance our understanding of shipwrecks?

The *Hazardous*, *Rooswijk* and *Invincible* case studies highlighted the possibility of creating a seamless integration of data from previous and current work that lead to more comprehensive interpretations presented in this thesis. It was observed that traditional methods of recording underwater continue to offer valuable information on artefact spatial distribution, construction techniques, ship fittings, and measurements. However, their capabilities are limited to the extent of the resolution they can offer. A 2D plan, side profile, and cross-section drawing offers a limited amount of survey points to plot on a plan. The 3D recording techniques offer the possibility to adquire millions of points in a relatively short time that can be processed into detailed plans (Figure 136, Figure 137, Figure 138 and Figure 139). This can be applied from extensive parts of the ships' structure to individual artefacts. Furthermore, the extensive integration of high-resolution techniques, such as the MBES and multi-image photogrammetry has not been applied previously in British waters to the extent presented in this thesis. Despite this progress, there is still more to be learned from the 2019 seasons working on the wrecks, with further non-disturbance surveys on *Hazardous* and *Rooswijk* and the final excavation season on *Invincible.*

The data captured throughout this project has created a digital archive of information that can be re-processed in the future by integrating data collected with new or enhanced techniques. For example, all the pictures taken for the multi-image photogrammetric surveys on *Hazardous, Rooswijk* and *Invincible* can be re-processed in the future with both hardware and software improvements, whereas traditional DSM (3H 2017; Rule 1989) will still give the same level of resolution, even in the future. By capturing this data in 3D systematically, this digital archive becomes extremely valuable for any project that wishes to record and preserve the site and its artefacts.

A standard sketch or drawing can have immense detail and interpretation of the structural elements of a vessel and the assembling methods, depending on who makes it (Figure 136 (A)). However, once created that is a still image with two-dimensions that cannot offer another perspective or angle. On the other hand, if done effectively and systematically, capturing a 3D data set will be consistently accurate, and one or two different operators (surveyors) can collect the data. The 3D model produced from the survey can then be manipulated in different positions, measured, scaled and compared with future surveys with the same geo-positioning system. Sketches or drawings have no less value, as Adams (2013a:44) pointed out it is a case of using the cognitive process of observation and visual analysis involved in drawing as a foundation for subsequent understanding and interpretation. Sketches and 3D recording are complimentary for interpreting wrecks sites. Nonetheless, a 3D model has more potential for empirical and quantitative analysis. With a 3D survey it is possible to obtain scaled measurements, dense clouds (Point cloud data), geo-positioning, DEMs, colours (Texture), and orthophotos in a cost-effective and quick way[409]. Furthermore, new technologies provide the opportunity to create Virtual Reality (VR)[410] and Augmented Reality (AR) environments (Napolitano, Scherer, and Glisic 2018; Rua and Alvito 2011; Soler, Melero, and Luzón 2017) (Figure 139), oferring the possibility for better public engagement activities and remote distance analysis (Figure 139).

[409] See Chapter III

[410] Cloud compare ®, Faroscene™, Prospect Pro Plus ®

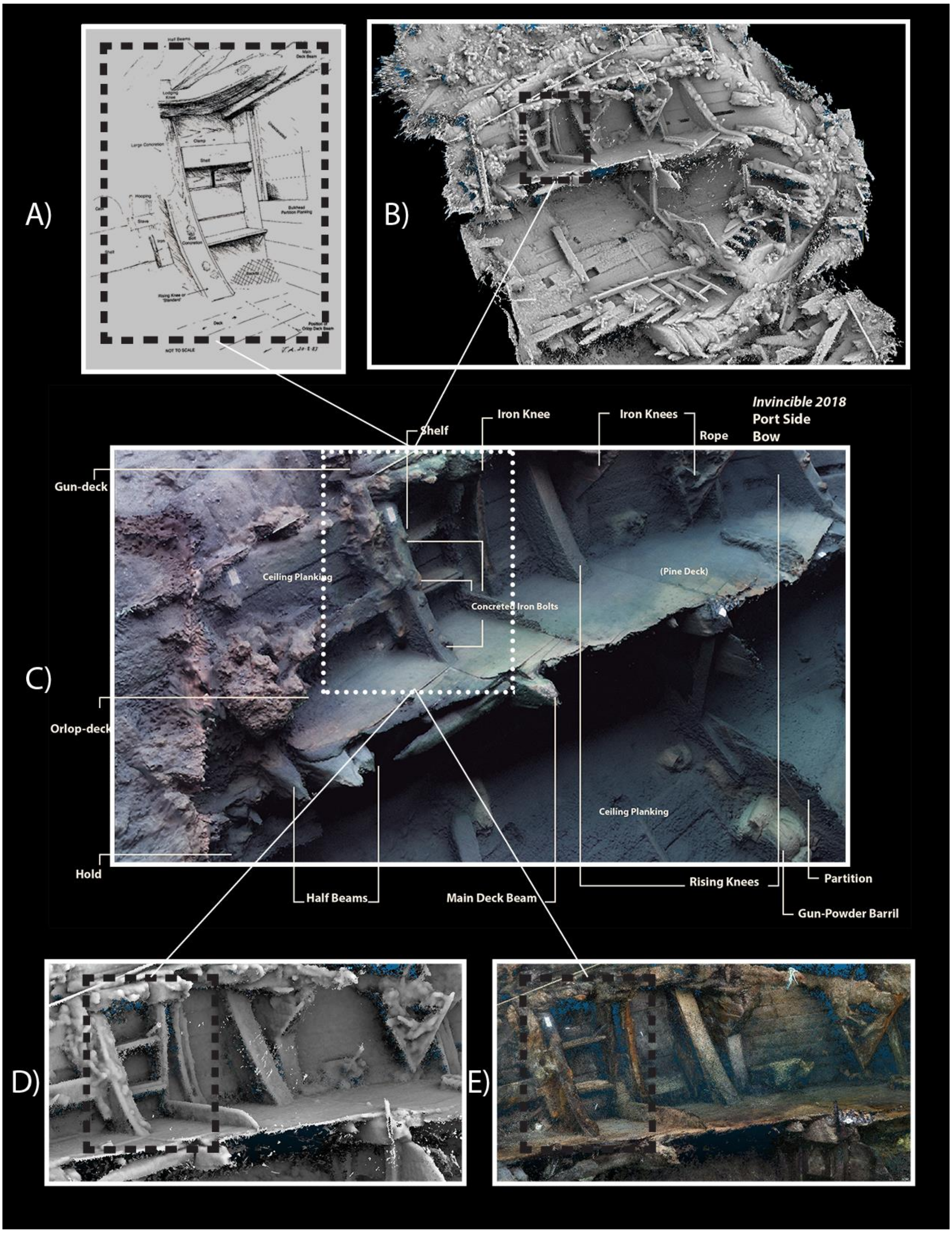

Figure 136. A) Adams sketch of shelve done 1983 in Bingeman (2010: 54) B) A dense cloud with PCV plug-in in Cloud Compare ®, C) Trench 1, port side close to the bow rendered in 3dSMax®, D) Close-up of shelving A dense loud with PCV plug-in in Cloud Compare ®, and E) RGB colours of dense cloud in Cloud Compare ®.

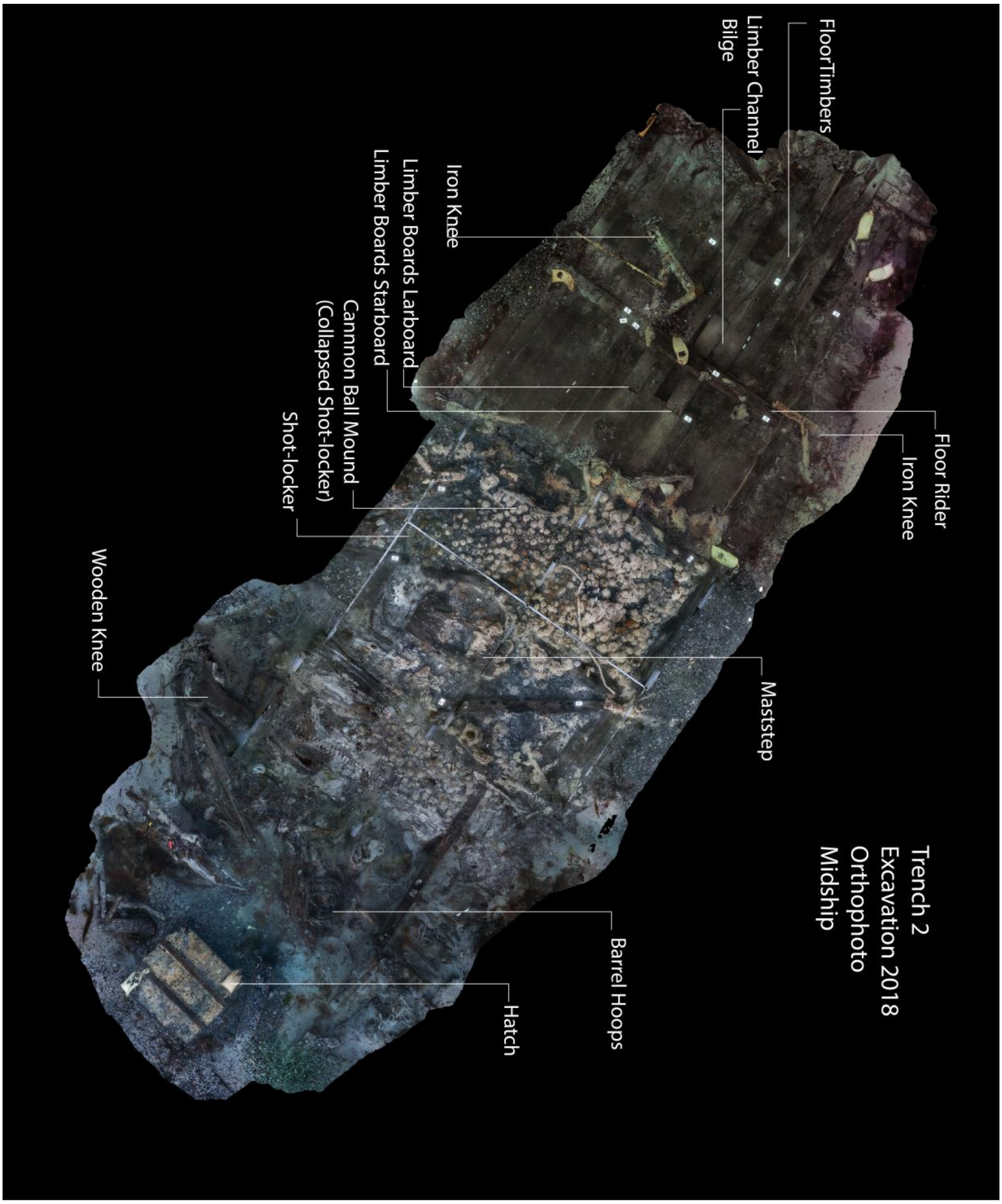

Figure 137. The figure shows a comparison of data-resolution. A) Site plan with Trench highlighted re-digitised from Bingeman (2010:57)**. B) A dense cloud created from multi-image photogrammetry processed in Agisoft Metashape Pro v1.5 ® and post post-processed in Cloud Compare® with PCV plug-in of Trench 2. C) An orthophoto created from multi-image photogrammetry in Agisoft Metashape Pro v1.5 ® processed in Cloud Compare® with PcV plug-in of Trench 2. The author of this thesis created the figure. Date courtesy of BU from the excavation of *Invincible* in 2018.**

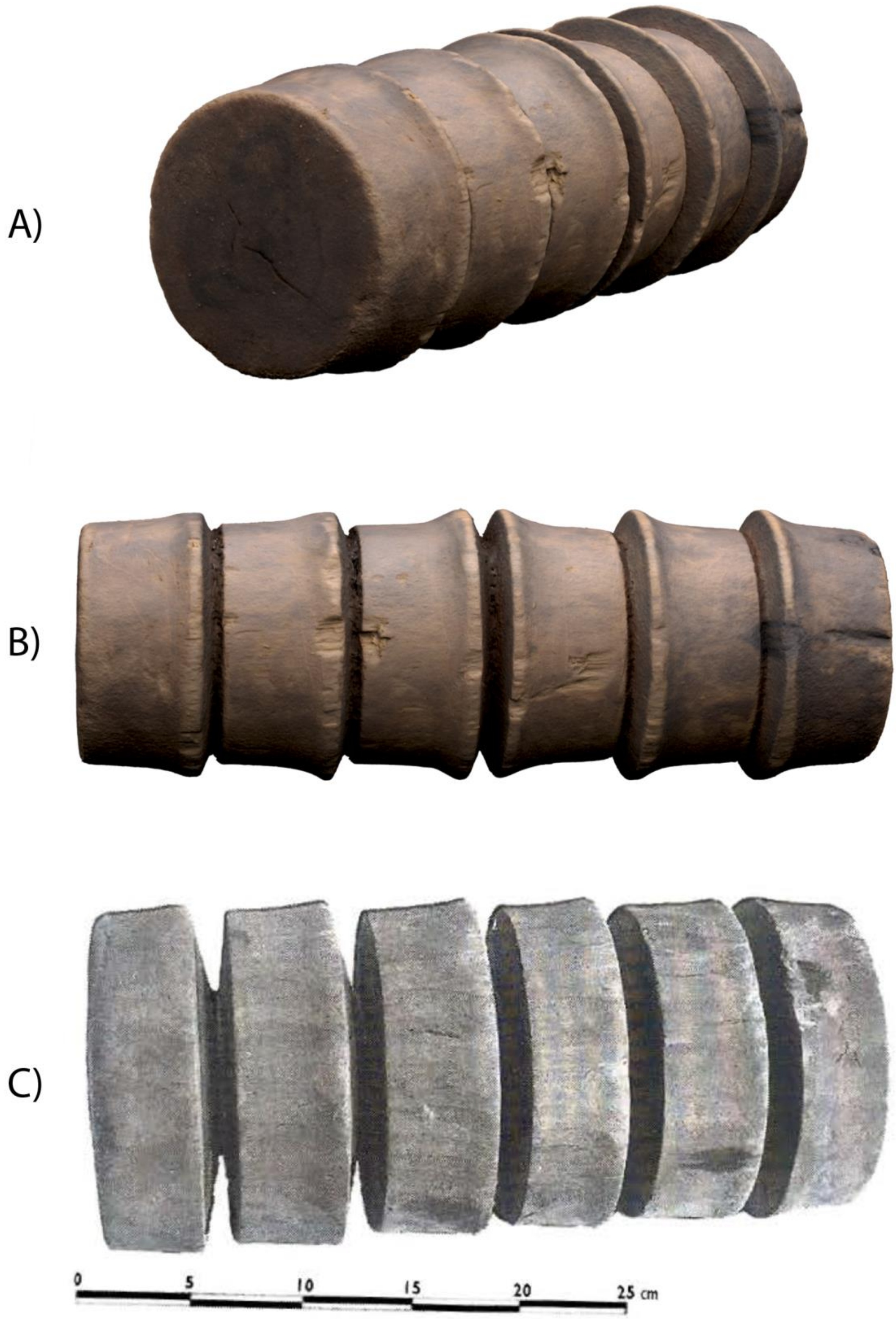

Figure 138. The figure represents different recording techniques. A) Perspective view of a spool of tampions rendered in 3DsMax®, B) Side view of a spool of tampions rendered in 3DsMax®, C) photograph in Bingeman (2010: 123).

Figure 139. The figure shows HTC Vive ® VR headset potential A) Public engagement during the NAS conference 2017, with Commander John Bingeman (MSDS Marine Ltd 2017)**.**
B) A double pulley block in Prospect Iris VR© C) Trench 2 from *Invincible* in 2018 Prospect Iris VR©, and D) Section of Trench 1, 2018 displayed in Faro scene™. The author of this thesis created the figure.

8.3 Final Remarks

Hazardous Prize, like many other Protected Wrecks in England, would benefit from more resources dedicated to its research, but there is often little eresources available for this. As such a professional team of archaeologists could work alongside the licensees, as succesfully occurred on the *Colossus* (Camidge 2017; Camidge et al. 2015; Morris 1979) *Yarmouth Roads* (Plets et al. 2008) *Stirling Castle* (Astley 2016; Astley et al. n.d.; Dunkley 2008; Pascoe and Peacock 2015; Wessex Archaeology 2003b) *Northumberland* (Pascoe, Mavrogordato, and Middleton 2015; Pascoe and Peacock 2015) and *London* (Artas Media 2018; PAS 2018b). This a reality confronted by cultural heritage across the globe, where the number of sites, monuments, artefacts, buildings, townscapes, cityscapes, or historical landscapes are all much larger than the available resources to protect and research them to the extent they required.

This is why, when given the opportunity to carry out research like that conducted on the *Rooswijk* and *Invincible* it is the responsibility of the archaeologist to record these sites to the best of our abilities. This is an extremely important challenge, and acknowledging the full potential of 3D and 4D recording for archaeological interpretation is the first step. The use of these technologies should not be encouraged because they are "flashy" or "trendy", but when done systematically, they are creating a digital record of the material culture of the past. The application of systemically integrated methodologies requires constantly keeping up-to-date with new technologies, and they should be encouraged to record cultural heritage whether it is submerged or on the surface.

Furthermore, one of the objectives of the UNESCO convention of 2001, is that the preservation *in situ* of underwater cultural heritage shall be considered as the first option (UNESCO 2001:3). However, as demonstrated in this thesis, not all underwater cultural heritage benefits from *in situ* preservation and this can be easily confused with site abandonment without an adequate project design, site management programme, and funding. If the *Hazardous, Rooswijk* and *Invincible* sites had not been excavated and/or extensively researched, our knowledge of the wrecks would be limited. Wrecks are finite resources in dynamic marine environments and therefore more archaeological research should be encouraged that includes both pre- and post-disturbance surveys.

Realistically, resources dedicated for Protected Wreck sites are limited and they require prioritising and targeting specific research questions. HE has increased the number of Protected Wrecks in recent years, and this number is likely to keep growing in the future[411] (English Heritage 2010; HE 2018b). Therefore, providing resources for all of the Protected Wrecks is a monumental task for heritage management. Marine geophysics have proven to be a cost-effective monitoring techniques as with the case studies presented in this thesis and on other wreck sites (Astley 2016; Bates et al. 2011; Fernández-Montblanc et al. 2016; Mattei and Giordano 2015; Plets et al. 2013; Quinn et al. 1998, 2016; Quinn and Smyth 2017). Therefore, more wrecks should be surveyed with high-resolution marine geophysical techniques, with a site-tailored methodology that offers the best possible resolution according to the site conditions; as demonstrated on the *Hazardous* (Chapter V), *Rooswijk* (Chapter VI) and *Invincible* (Chapter VII). However, marine geophysics are limited in the interpretation that they can offer on the wrecks on an intra-site level. Therefore, traditional archaeological methods and *in situ* observation cannot be replaced by remote sensing techniques. Rather, they should continue to be used to complement and enhance the remote sensing interpretations. The application of flexible integrated methodologies such as the one presented in this thesis should be encouraged for future research, monitoring, assessments, and evaluations of wreck sites[412].

This thesis presented improved archaeological interpretations based on newly collected data, its integration and analysis. For example, the artefact distribution pattern on *Rooswijk* revealed interesting site formation processes. The fact that the shipwreck structure is absent does not mean it is not possible to understand the wrecking process and the shipboard associations. Re-visiting the *Rooswijk* represented

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[411] There are 53 Protected Wreck sites in England in 2019. In 2010, there were 47 Protected Wrecks in England.

[412] Seabed Habitats was initiated in EMODnet Phase I (2009-2013) through the EUSeaMap project. During the current Phase III (2017-2020), Seabed Habitats will extend the work carried out during the preparatory Phases to move from a prototype to an operational service delivering full coverage of a broad-scale map for all European sea-basins, along with the dissemination of maps from surveys (EMODnet 2018).

a rare opportunity to trace artefact distribution and classify its type. In particular, the distribution of silver specie revealed a pattern that allowed identifying the remains of the Captain Cabin and stern of the ship. As Martin pointed out, the more dynamic and destructive the wreck formation processes, the greater will be the demands on archaeologists who seek to record and understand them (Martin 2005:208), and the *Rooswijk* definitely proved to be demanding. Unfortunately, not all of the VOC, Spanish Galleons or Portuguese carracks, amongst other wrecks transporting specie, have had the same that level of detailed recording. Through either modern commercial salvage, or insufficient recording techniques during archaeological excavations, crucial shipboard associations have been lost, or rendered unclear.

A continuous collaboration on projects carried out on *Invincible* since 2013, offered the opportunity to create a systematic methodology that was later applied to the other case studies. It is important to recognise that the application of multi-image photogrammetry, in particular, was greatly improved throughout the development of this thesis, resulting in a systemic workflow, from the acquisition of data to the post-processing stage. This process has transformed my recording methods for maritime heritage on a variety of sites ranging from submerged prehistoric deposits to modern structures and even museum collections.

8.4 Further Research

The shipwreck classification based on the environment and shipwreck integrity should be expanded to include other historical Protected Wrecks sites (Wales, Scotland and Northern Ireland), Designated Control Sites of Military Remains, and ESB[413] wrecks around the UK (Appendix I). This system, based on marine environmental energy-levels and the ships' structural remains, encompasses a wide range of wrecks[414]. Furthermore, this classification can be extended to other regions in European seas, The Mediterranean and Back Sea. Considering that there are another three million wreck sites across the globe, this could generate a unified system to understand their broad or macro-scale dynamics.

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413 Early Ships and Boats, identified by Wessex Archaeology (2013).
414 See Table 20, Table 21 and Table 22.

It must be acknowledged that certain limitations were encountered during the research for data acquisition, mainly dictated by the environmental conditions including days lost to bad weather, reduced visibility limiting the capacity to carry out surveys, short-windows to work underwater dictated by the tide and fieldwork carried out only during summer months. However, that is the nature of working at sea.

Further 4D and VR/AR integration could be explored in the future to analyse or present site formation processes on UCH. Specifically, on the *Invincible* a full VR-3D integration of the remaining structure and the artefacts found within it would enhance the understanding of shipboard relationships (Figure 136, Figure 137 and Figure 138). Nonetheless, the first steps forward have already been made in this direction to integrate the information on an interactive platform such as the virtual trail created for the *Invincible* and *Rooswijk* (HE et al. 2018; MSDS Marine Ltd & Artas Media 2018a; PAS & Artas Media 2016; PAS & MSDS Marine Ltd 2018).

This thesis ventured to combine theory, methods and employ a variety of practices to represent the site formation processes of submerged shipwrecks in 4D. The use of integrated methodologies provided the means of seeing past murky waters and interpreting the archaeological record on a macro, meso and intra-site level. The combination of pre- and post-disturbance surveys as well as continued site monitoring, was essential to understand site dynamics. It is important to recognise that information gathered during the excavations of the *Hazardous, Rooswijk* and *Invincible* provide a greater level of intra-site interpretations: allowing seeing past the seabed surface, that otherwise would have been impossible to capture the complexity of the wrecks' extant remains and their surrounding dynamic environments. Thus, further integrated archaeological research should be encouraged on other wreck sites to gather more multiple-level interpretations with scientifically credible narratives of past human activities on the seas.

Bibliography

2GRobotics. 2017. “ULS-500 PRO Dynamic Underwater Laser Scanner.” Retrieved December 12, 2017 (https://www.2grobotics.com/products/underwater-laser-scanner-uls-500/).

3D at Depth. 2018a. “Dynamic LiDAR Moving Platform.” *2018*. Retrieved (https://www.3datdepth.com/product/dynamic-lidar-moving-platform).

3D at Depth. 2018b. “SLS 1.” *2018*. Retrieved May 10, 2018 (https://www.3datdepth.com/).

3H. 2006. *Site Recorder 4: The GIS for Maritime Archaeology*. Plymouth.

3H. 2017. “Techniques: 3D Trilateration or the Direct Survey Method (DSM).” *Site Recorder*. Retrieved December 11, 2017 (http://www.3hconsulting.com/techniques/Tech3DTrilatDSM.html).

Aalberg, Contributors Trond, Detlev Balzer, Chryssoula Bekiari, Lina Boudouri, Nick Crofts, Øyvind Eide, Tony Gill, Günther Goerz, Monika Hagedorn, Gerald Hiebel, Juha Inkari, Dolores Iorizzo, Juha Kotipelto, Siegfried Krause, Karl Heinz Lampe, Jutta Lindenthal, Mika Nyman, Pat Riva, Lene Rold, Richard Smiraglia, Regine Stein, Matthew Stiff, and Maja Žumer. 2019. “Definition of the CIDOC Conceptual Reference Model Documentation Standards Group V6.”

Adams, Jon. 1988. *Unpublished Mary Rose Trust Internal Report.* Portsmouth.

Adams, Jonathan. 1990. "The Oskarshamn Cog. Part II: Excavation, Underwater Recording and Salvage." *International Journal of Nautical Archaeology* 19(3):207–19.

Adams, Jonathan. 2013a. *A Maritime Archaeology of Ships: Innovation and Social Change in Medieval and Early Modern Europe.* Oxford: Oxbow.

Adams, Jonathan. 2013b. "Experiencing Shipwrecks and the Primacy of Vision." in *Interpreting Shipwrecks, Maritime Archaeological Approaches*, edited by J. Adams and J. Rönnby. Southampton: Highfield Press.

Adams, Jonathan and Johan Rönnby. 2013a. "Landscapes, Seascapes and Shipscapes." Pp. 1–8 in *Interpreting Shipwrecks, Maritime Archaeological Approaches*, edited by J. Adams and J. Rönnby. Southampton: Highfield Press.

Adams, Jonathan and Johan Rönnby. 2013b. "One of His Majesty's 'Beste Kraffwells': The Wreck of an Early Carvel-Built Ship at Franska Sternarna, Sweden." *International Journal of Nautical Archaeology* 42(1):103–17.

Adams, W. Y. and E. W. Adams. 2007. *Archaeological Typology and Practical Reality: A Dialectical Approach to Artifact Classification and Sorting*. Cambridge: Cambridge University Press.

ADM/L/J/ 87. 1758. "Lieutenant's Logs."

ADM/Y/5. 1758. "PRO Series."

ADM. 1758. "ADM95/25, No67."

ADM. 1934. "The Solent- Eastern Part Including Spithead."

ADM. 1970. “The Solent Eastern Part.”

ADM. 1974. “The Solent Eastern Part.”

ADM. 2000. “The Solent Eastern Part.”

ADM. 2005. “The Solent Eastern Part.”

ADM 106/1191. 1758. “PRO Series.”

ADM 2/522. 1758. “PRO Series.”

ADM 51/673. 1758. “PRO Series.”

ADU. 2001. *Hazardous Wreck Information Folder. 1987 - 2001*. St Andrews.

Alcaro, L., E. Amato, Fh Cabioch, C. Farchi, and V. Gouriou. 2007. “DEEPP Project Development of European Guidelines for Potentially Polluting Shipwrecks.” *DEEPP Project* (September).

Anchor Dive Lights. 2018. “Series 5k Spot – 15° Spot / 120° Wide.” Retrieved February 19, 2018 (https://anchordivelights.com/product/series-5k-spot-15-spot-120/).

Anweiler, S. 2017. “Development of Videogrammetry as a Tool for Gas-Particle Fluidization Research.” *Journal of Environmental Management* 203:942–49.

Applanix. 2017. “POS MV WAVEMASTER II SPECIFICATIONS.” 6–7.

Aragón, Enrique, Sebastia Munar, Javier Rodríguez, and Kotaro Yamafune. 2018. “Underwater Photogrammetric Monitoring

Techniques for Mid-Depth Shipwrecks." *Journal of Cultural Heritage*.

Archaeology, Wessex. 2006. *Kennemerland, Out Skerries, Shetland Isles. Designated Site Assessment: Archaeological Report*. Salisbury.

Artas Media. 2018. "The Wreck of the London." *2017*. Retrieved April 22, 2018 (https://www.cloudtour.tv/london).

Ashley, G. M. 1990. "Classification of Large-Scale Subaqueous Bedforms: A New Look at an Old Problem." *Journal of Sedimentary Petrology* 60(1):160–172.

Association for Geographic Information. 2012. "UK GEMINI Specification for Discovery Metadata for Geospatial Data Resources." (December):0–62.

Astley, Amelia, Duncan Brown, Gill Campbell, Kathryn Dagless, David Dungworth, Julian Whitewright, and Duncan Brown. n.d. "The Stirling Castle, a 70-Gun Ship Lost in the Great Storm of 1703: Archaeological and Historical Archive, 1979-2009: Maritime Archaeology Trust Monograph Series (No. 4), within the British Archaeological Reports British Series."

Astley, Amelia J. 2016. "The Taphonomy of Historic Shipwreck Sites." University of southampton.

Babits, L. E. and H. Van Tilburg. 2013. *Maritime Archaeology: A Reader of Substantive and Theoretical Contributions*. Springer US.

Baeye, M., R. Quinn, S. Deleu, and M. Fettweis. 2016. "Detection of Shipwrecks in Ocean Colour Satellite Imagery." *Journal of Archaeological Science* 66:1–6.

Baker, Patrick E. and Jeremy N. Green. 1976. “Recording Techniques Used during the Excavation of the Batavia.” *International Journal of Nautical Archaeology* 5(2):143–58.

Balletti, C., C. Beltrame, E. Costa, F. Guerra, and P. Vernier. 2016. “3D Reconstruction of Marble Shipwreck Cargoes Based on Underwater Multi-Image Photogrammetry.” *Digital Applications in Archaeology and Cultural Heritage* 3(1):1–8.

Banco de Mexico. 2018. *Historia de La Moneda y Del Billete En México*. Mexico City.

Barber, J. W. and B. A. Crone. 1993. “Crannogs; a Diminishing Resource? A Survey of the Crannogs of Southwest Scotland and Excavations at Buiston Crannog.” *Antiquity* 67(256):520–33.

Basch, Lucien. 1972. “Ancient Wrecks and the Archaeology of Ships.” *International Journal of Nautical Archaeology* 1(1):1–58.

Basch, Lueien. 1973. “The Golo Wreck and Sidelights on Other Ancient Ships Culled from Admiral Paris’Souvenirs de Marine Conservés.” *International Journal of Nautical Archaeology* 2(2):329–44.

Bass, George. 1968. “New Tools for Undersea Archaeology.” *National Geographic* (134):403-422.

Bass, George. 2012. “Cape Gelidonya Shipwreck.” in *The Oxford Handbook of the Bronze Age Aegean*, edited by E. H. Cline. Oxford: Oxford University Press.

Bass, George and Frederick van Doorninck. 1982. *Yassi Ada Vol. I: A Seventh-Century Byzantine Shipwreck.* Rachal Fou. Texas A&M University Press.

Bass, George F. 1961. “The Cape Gelidonya Wreck: Preliminary Report.” *American Journal of Archaeology* 65(3):267–76.

Bass, George F. 1980. *Marine Archaeology: A Misunderstood Science*. Vol. 2.

Bass, George F. and Frederick H. Van Doorninck. 1978. “An 11th Century Shipwreck at Serge Liman , Turkey.” *American Institute of Nautical Archaeology* (4):119–32.

Bass, George F., Cemal Pulak, Dominique Collon, James Weinstein, George F. Bass, Cemal Pulak, Dominique Collon, and James Weinstein. 1989. “The Bronze Age Shipwreck at Ulu Burun : 1986 Campaign.” *American Journal of Archaeology* 93(1):1–29.

Batchvarov, Kroum. 2016. “Archaeology of a 17th-Century Naval Battle: The First Two Seasons of the Rockley Bay Research Project in Tobago.” *International Journal of Nautical Archaeology* 45(1):105–18.

Bates, C. Richard, Mark Lawrence, Martin Dean, and Philip Robertson. 2011. “Geophysical Methods for Wreck-Site Monitoring: The Rapid Archaeological Site Surveying and Evaluation (RASSE) Programme.” *International Journal of Nautical Archaeology* 40(2):404–16.

Bax, Alan and Colin J. M. Martin. 1974. “De Liefde. A Dutch East Indiaman Lost on the Out Skerries , Shetland , in 1711.” *International Journal of Nautical Archaeology* 81–90.

Beattie-Edwards, Mark. 2014. *Condition Assessment of the Holland No.5 Submarine*. Port.

Beattie-Edwards, Mark. 2017. *Norman’s Bay Wreck , Pevensey Bay , East Sussex Conservation Statement and Management Plan*.

Portsmouth.

Beattie-Edwards, Mark. 2018. *The Rooswijk. SCUBA Support Project. Project Report 2017. Rooswijk Protected Wreck Site, Goodwin Sands. Archaeological Excavation and Preservation*. Portsmouth.

Beattie-Edwards, Mark, Peter Le Fevre, and Frank Fox. 2017. "The Norman's Bay Shipwreck, East Sussex, UK: A Possible 17th-Century Dutch Ship from the Battle of Beachy Head." *International Journal of Nautical Archaeology* (June 2006):1–23.

Becker, J. J., D. T. Sandwell, W. H. F. Smith, J. Braud, B. Binder, J. Depner, D. Fabre, J. Factor, S. Ingalls, S. H. Kim, R. Ladner, K. Marks, S. Nelson, A. Pharaoh, R. Trimmer, J. von Rosenberg, G. Wallace, and P. Weatherall. 2009. "Global Bathymetry and Elevation Data at 30 Arc Seconds Resolution: SRTM30_PLUS." *Marine Geodesy* 32(4):355–71.

Bentam, Charles. 1742a. "Model van Een Oostindiëvaarder Op Scheepskamelen."

Bentam, Charles. 1742b. "VOC Retourschip."

Bernier, Marc-André. 2007. "Site Formation Process Break-Up of the 24M Vessel." Pp. 215–90 in *The Underwater Archaeology of Red Bay: Basque shipbuilding and whaling in the 16th century*, edited by R. Grenier, M.-A. Bernier, and W. Steves. Parks Canada.

Berry, Jessica and Kevin Camidge. 2012. *Coronation. Geophysical Survey*.

Berthling, Ivar and Bernd Etzelmüller. 2011. "The Concept of Cryo-Conditioning in Landscape Evolution." *Quaternary Research*

75(02):378–84.

Bevan, John. 1996. *The Infernal Diver: He Lives of John and Charles Deane, Their Invention of the Diving Helmet, and Its First Application to Salvage, Treasure Hunting, Civil Engineering and Military Uses*. London: Submex Ltd.

Bevan, John. 1999a. "SEMI-ATMOSPHERIC DIVING SYSTEMS." *SPUMS* 29(3):167–73.

Bevan, John. 1999b. "The Diving Helmet." *SPUMS* 29(2):109-.

BGS. 2006. *SEM Petrography of Samples of the London Clay of Southern England*. Nottinham.

BGS. 2018a. "He BGS Lexicon of Named Rock Units-Result Details. Bracklesham Group." Retrieved July 28, 2018 (http://www.bgs.ac.uk/Lexicon/lexicon.cfm?pub=BRB).

BGS. 2018b. "Marine Sediments. Offshore Products WMS/MapServer." *WMS*. Retrieved February 22, 2018 (https://map.bgs.ac.uk/arcgis/services/Offshore/Products_WMS/MapServer/WmsServer).

Bide, T. P., P. S. Balson, J. M. Mankelow, R. A. Shaw, Walters A.S., and E. Campbell. 2013. *The Mineral Resources of the English Channel and Thames Estuary*.

Biegański, Wojciech and Andrzej Kasiński. 2012. "Image Acquisition in an Underwater Vision System with NIR and VIS Illumination." *Institute of Control and Information Engineering, Poznań University of Technology, Poznań, Poland* 215–24.

Bierwirth, Phil, Richard Blewett, and David Huston. 1998. "Finding New Mineral Prospects with HYMAP : Early Results from a

Hyperspectral Remote-Sensing Case Study in the West Pilbara." *Agso Research Newsletter* (c):1998–2000.

Billy, Ballast, Blanche King, Cristobal Colon, L. Herminie, and North Carolina. 2007. *Ministry of the Environment , Telecommunications and E-Commerce*. Hamilton\.

Binford, Lewis. 1983. *In Pursuit of the Past. Decoding the Archaeological Record*. London: University of California Press.

Binford, Lewis R. 1977. *For Theory Building in Archaeology : Essays on Faunal Remains, Aquatic Resources, Spatial Analysis and Systemic Modeling.* New York: Academic Press.

Bingeman, John. 1981. *Solent: HMS Invincible 1758 Wreck Site*. Vol. 10.2.

Bingeman, John. 1985. "Interim Report on Artefacts Recovered from Invincible (1758) between 1974 and 1984." *International Journal of Nautical Archaelogy* 14.3:191–210.

Bingeman, John. 2010. *The First HMS Invincible (1747-58) Her Excavations (1980-1991)*. Oxford: Oxbow Books.

Björdal, Charlotte Gjelstrup, David Gregory, Martijn Manders, Zyad Al-Hamdani, Christin Appelqvist, Jon Haverhand, and Jörgen Dencker. 2012. "Strategies for Protection of Wooden Underwater Cultural Heritage in the Baltic Sea Against Marine Borers: The EU Project 'WreckProtect.'" *Conservation and Management of Archaeological Sites* 14(1–4):201–14.

Blake, Warren and Jeremy Green. 1986. "A Mid-XVI Century Portuguese Wreck in the Seychelles." *International Journal of Nautical Archaeology* 15(1):1–23.

Blue, Lucy and Tamsyn Smith. 2014. "Ports and Harbours." *Shipwrecks and Submerged Worlds: Maritime Archaeology. MOOC*. Retrieved April 5, 2018 (http://moocs.southampton.ac.uk/shipwrecks/2014/10/08/ports-harbours/).

Blundell, Rev. Odo. 1909a. "Examination of Artificial Island in Loch Ness." *Proceedings of the Society of Antiquaries Scotland* 43:159–64.

Blundell, Rev. Odo. 1909b. "On Further Examination of Artifitial Islands in the Beauly Frith, Loch Bruiach, Loch Moy, Loch Garry, Loch Lundy, Loch Oich, Loch Locky, and Loch Treig." *Proceedings of the Society of Antiquaries Scotland* 44:12–33.

BODC. 2018a. "UK Tide Gauge Network." *2018*. Retrieved April 25, 2018 (https://www.bodc.ac.uk/data/hosted_data_systems/sea_level/uk_tide_gauge_network/).

BODC. 2018b. "Waves." *2018*. Retrieved April 29, 2018 (https://www.bodc.ac.uk/data/bodc_database/waves/).

Booth, Tony. 2007. *Admiralty Salvage in Peace and War 1906 - 2006: Grope, Grub and Tremble*. Barnsley: Pen & Sword Books Ltd.

Boudriot, Jean. 1973. *The Seventy-Four Gun Ship. A Practical Treatise on the Art of Naval Architecture. Vol. 1 Hull Construction*. edited by D. H. Roberts. Paris: Collection Archaeologie Navale Fracaise.

Boudriot, Jean. 1975. *The Seventy-Four Gun Ship. A Practical Treatise on the Art of Naval Architecture. Vol. 3 Masts-Sails-Rigging*. Vol. 3. David H. R. Paris: Collection Archaeologie

Navale Fracaise.

Bradburn, Douglas. 2011. “The Visible Fist: The Chesapeake Tobacco Trade in War and the Purpose of Empire, 1690–1715.” *The William and Mary Quarterly* 68(3):361–86.

British Academy & Honor Frost Foundation. 2014. *2001 UNESCO Convention on the Protection of the Underwater Cultural Heritage. The Case for UK Ratification*. London: Aspect Press.

Bruijn, J. R., F. S. Gaastra, and Ivo Schöffer. 1979. *Dutch-Asiatic Shipping in the 17th and 18th Centuries, Volume II, Outward-Bound Voyages from the Netherlands to Asia and the Cape (1595-1794).* Nijhoff.

Bull, Jonathan M., Martin Gutowski, Justin K. Dix, Timothy J. Henstock, Peter Hogarth, Timothy G. Leighton, and Paul R. White. 2005. “Design of a 3D Chirp Sub-Bottom Imaging System.” *Marine Geophysical Researches* 26(2–4):157–69.

Burnett, Joe. 2013. “Processing Your Patch Test Data in the New MBMAX64.” 1–21.

Bynoe, Rachel. 2017. *Investigating the Submerged Pleistocene Landscapes of the Wallet, off Clacton*. Portsmouth.

Bynoe, Rachel, Justin K. Dix, and Fraser Sturt. 2016. “Of Mammoths and Other Monsters: Historic Approaches to the Submerged Palaeolithic.” *Antiquity* 90(352):857–75.

Camidge, K. 2007. *St Anthony Finds Record*. Penzance.

Camidge, Kevin. 2008. *Rill Cove Finds Record Project Report*.

Camidge, Kevin. 2013a. *Rill Cove. Desl-Based Assessment*.

Camidge, Kevin. 2013b. *Schiedam Prize. Desk Based Assessment*.

Camidge, Kevin. 2013c. *St Anthony Desk-Based Assessment*. Penzance.

Camidge, Kevin. 2017. *Colossus Wrecking Project*.

Camidge, Kevin, Gill Campbell, Damien Sanders, Polydora Baker, Jezz Davies, and Mags Felter. 2015. *HMS Colossus Investigation 2015*.

Camidge, Kevin and Charles Johns. 2014. *Royal Anne Galley Marine Environmental Assessment The Lizard, Cornwall. Phase 4 Monitoring : Initial Inspection and Monitoring*. Truro.

Camidge, Kevin and Charles Johns. 2016a. *Bartholomew Ledges , St Mary's Sound , Isles of Scilly Conservation Statement & Management Plan Cornwall Archaeological Unit Bartholomew Ledges*. Truro.

Camidge, Kevin and Charles Johns. 2016b. *Royal Anne Galley , The Lizard , Cornwall Conservation Statement & Management*.

Camidge, Kevin and Charles Johns. 2017. *Tearing Ledge , Western Rocks , Isles of Scilly : Conservation Statement and Management Plan*. Penzance.

Camidge, Kevin, Charles Johns, and Phillip Rees. 2006. *Royal Anne Galley, Lizard Point, Cornwall. Marine Environmental Assessment Phase 1 Desk-Based Assessment*. Truro.

Cant, Serena. 2013. *England's Shipwreck Heritage: From Logboats to U-Boats. Swindon: English Heritage.* Swindon: Historic England.

Capturing Reality. 2019. “Reality Capture.” Retrieved February 1, 2019 (https://www.capturingreality.com/Product).

Carrizales, A. 2010. “Development and Refinement of Regional Sediment Mobility Models : Implications for Coastal Evolution, Preservation of Archaeological Potential, and Commercial Development.” University of Southampton.

Castro, Filipe. 2003. *A Nau de Portugal.* Lisboa: Ediçao de Livros e Revistas, Lda.

CCO. 2018. “Map Viewer and Data Catalogue.” Retrieved February 21, 2018 (https://www.channelcoast.org/data_management/online_data_catalogue/).

CEFAS. 2018. “Smart Buoys.” *2018*. Retrieved April 29, 2018 (https://www.cefas.co.uk/cefas-data-hub/smartbuoys/).

Ceraudo, Giuseppe. 2013. “Good Practice in Archaeological Diagnostics.” Pp. 11–31 in *Non-invasive Survet of Complex Archaeological Sites*, edited by C. Corsi, B. SlapSak, and V. F. New York: Springer.

Chang, Grace, Kevin Mahoney, Amanda Briggs-Whitmire, David Kohler, Curtis Mobley, Marlon Lewis, Mark Moline, Emmanuel Boss, Minsu Kim, William Philpot, and Tommy Dickey. 2012. “The New Age of Hyperspectral Oceanography.” *Oceanography* 17(2):16–23.

Chapman, Andrew. 2016. “Types of Drones: Multi-Rotor vs Fixed-Wing vs Single Rotor vs Hybrid VTOL.” *DRONE*, June.

Chen, Lisa and Romain Pinel. 2017. “Diving into Underwater Photogrammetry.” *Pix4D*. Retrieved January 16, 2018 (https://pix4d.com/diving-into-underwater-photogrammetry/).

CISMAS. 2017. “Site of Tearing Ledge.” *2017*. Retrieved April 17, 2018 (https://sketchfab.com/models/c2221cd67d004204b703b9ee9ef82cde).

CISMAS. 2018a. “The Wreck of the Association.” *2018*. Retrieved April 23, 2018 (https://skfb.ly/6vVXO).

CISMAS. 2018b. “Wheel Wreck High Resolution Mesh.” *2017*. Retrieved April 22, 2018 (https://skfb.ly/6yv9H).

Clarke, D. 1972. “Archaeology : The Loss of Innocence.” *Antoquity* 47:6–18.

Clarke, David. 1972. “Models and Paradigms in Contempory Archaeology.” Pp. 1–60 in *Models in Archaeology*. Cambridge: Methuen and Co Ltd.

Cloet, R. L. 1954. “Hydrographic Analysis of the Goodwin Sands and the Brake Bank.” *The Geographical Journal* 120(2):203–15.

Cobbett, William. 1810. *The Parliamentary History of England, from the Earliest Period to the Year 1803. From Which Last-Mentioned Epoch It Is Continued Downwards in the Work Entititled, “The Parliamentary Debats”.* London: T.C. Hansard.

Colldege, J. and Ben Warlow. 2010. *Ships Of The Royal Navy: A Complete Record of All Fighting Ships of the Royal Navy from the 15th Century to the Present*. Havertown, PA: CASEMATE.

Collections Trust. 2019. “Spectrum.” *2017*. Retrieved (https://collectionstrust.org.uk/spectrum/).

Connor, D. W., P. M. Gilliland, N. Golding, P. Robinson, D. Todd, and E. Verling. 2006. *UKSeaMap: The Mapping of Seabed and Water Column Features of UK Seas*. Peterborough.

Connor, David W., James H. Allen, Neil Golding, L. Kerry, Louise M. Lieberknecht, Kate O. Northen, and Johnny B. Reker. 2004. *The Marine Habitat Classification for Britain And Ireland*. Peterborough.

Cook, David. 2016. *Goodwin Sands Aggregate Dredging Environmental Statement*. Vol. II. London.

Cooper, John P., Andrew Wetherelt, Chiara Zazzaro, and Matthew Eyre. 2018. "From Boatyard to Museum: 3D Laser Scanning and Digital Modelling of the Qatar Museums Watercraft Collection, Doha, Qatar." *International Journal of Nautical Archaeology* 47(2):419–42.

Cotswold Archaeology Marine. 2014. *Cotswold Archaeology Marine NHPP 3A1 : Unknown Marine Assets & Landscapes Strategic Assessment of Submarines in English Waters*. Cirencester.

Cousteau, Jacques-Yves and Frédéric Dumas. 1953. *The Silent World*. National Geographic Society.

Cowan, Rex, Zélide Cowan, and Peter Marsden. 1975. "The Dutch East Indiaman Hollandia Wrecked on the Isles of Scilly in 1743." *International Journal of Nautical Archaeology* 4(2):267–300.

Crisman, Kevin. 1999. "Angra B: The Lead-Sheathed Wreck at Porto Novo." *Revista Portuguesa de Arqueologia* 2.1:255 – 261.

Crown. 1973. "Protection of Wrecks Act 1973."

Crumlin-Pedersen, O. and S. McGrail. 2006. "Some Principles for the Reconstruction of Ancient Boat Structures.” *International Journal of ….*

Curry, D., A. D. King, C. King, and F. C. Stinton. 1977. “The Bracklesham Beds (Eocene) of Bracklesham Bay and Selsey, Sussex.” *Proceedings of the Geologists’ Association* 88(4):243–54.

Danielson, Jeffrey J. and Dean B. Gesch. 2011. “Global Multi-Resolution Terrain Elevation Data 2010.” *Terrain* 2010:iV, 26.

Daykin-iliopoulos, Paris and Tom Cousins. 2013. *Gull Rock Wreck & Iona II Licensee Site Report*. Bournmouth.

Dean, Martin, Ben Ferrari, Ian Oxley, Mark Redknap, and Kitts Watson. 1992. “Archaeology Underwater: The NAS Guide to Principles and Practice.” *International Journal of Nautical Archaeology* 65.

Deetz, James. 1967. *Invitation to Archaeology*. New York: Natural History Press for the American Museum of Natural History.

DEFRA. 2018. “About Us.” Retrieved July 31, 2018 (https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs/about).

Dellino-Musgrave, Virginia. 2006. *Maritime Archaeology and Social Relations: British Action in the Southern Hemisphere*. New York: Springer New York.

Demesticha, Stella, Dimitrios Skarlatos, and Andonis Neophytou. 2014. “The 4th-Century B.C. Shipwreck at Mazotos, Cyprus: New Techniques and Methodologies in the 3D Mapping of Shipwreck Excavations.” *Journal of Field Archaeology* 39(2):134–50.

Devlin, M. J., J. Barry, D. K. Mills, R. J. Gowen, J. Foden, D. Sivyer, N. Greenwood, D. Pearce, and P. Tett. 2009. "Estimating the Diffuse Attenuation Coefficient from Optically Active Constituents in UK Marine Waters." *Estuarine, Coastal and Shelf Science* 82(1):73–83.

Dewberry. 2013. *Coastal California Data Merge Project. Report Produced for the National Oceanic and Atmospheric Administration (NOAA)*. Tampa, FL.

Dhoop, Thomas. 2016. "Shaped by Ships and Storms: A Maritime Archaeology of Medieval Winchelsea." University of Southampton.

Diaz-Andreu, Margarita. 2015. *Ethnic Identity and Ethnicity in Archaeology*. Vol. 8. Second Edi. Elsevier.

Dickey, T. and M. Lewis. 2012. "Optical Oceanography : Recent Advances and Future Directions Using Global Remote Sensing and in Situ Observations." *In Situ* (2003):1–39.

Dierssen, Heidi M. 2013. "Overview of Hyperspectral Remote Sensing for Mapping Marine Benthic Habitats from Airborne and Underwater Sensors." *Imaging Spectrometry XVIII* 8870(September 2013):88700L.

Dierssen, Heidi M. and Kaylan Randolph. 2013. "Remote Sensing of Ocean Color." Pp. 439–72 in *Earth System Monitoring. Selected Entries from the Encyclopedia of Sustainability Science and Technology*, edited by J. Orcutt. New York: Springer.

Dix, J., A. Bastos, R. Plets, Dj Bull, and Dt Henstock. 2006. *High Resolution Sonar for the Archaeological Investigation of Marine Aggregate Deposits*.

Dix, Justin. 2000. *Sedimentation-Erosion Modelling as a Tool for Underwater Cultural Heritage Management*. Rotterdam.

Dobbs, C. T. C. and R. A. Price. 1991. “The Kennemerland Site. An Interim Report. The Sixth and Seventh Seasons, 1984 & 1987, and the Identification of Five Golf Clubs.” *International Journal of Nautical Archaeology* 20(2):111–22.

Drap, Pierre. 2012. “Underwater Photogrammetry for Archaeology.” *Special Applications of Photogrammetry*.

Drap, Pierre, Djamal Merad, Bilal Hijazi, Lamia Gaoua, Mohamad Motasem Nawaf, Mauro Saccone, Bertrand Chemisky, Julien Seinturier, Jean Christophe Sourisseau, Timmy Gambin, and Filipe Castro. 2015. “Underwater Photogrammetry and Object Modeling: A Case Study of Xlendiwreck in Malta.” *Sensors (Switzerland)* 15(12):30351–84.

Drap, Pierre, Julien Seinturier, Bilal Hijazi, Djamal Merad, Jean-Marc Boi, Bertrand Chemisky, Emmanuelle Seguin, and Luc Long. 2015. “The ROV 3D Project.” *Journal on Computing and Cultural Heritage* 8(4):1–24.

Dresch, Patrick and Sally Evans. 2017. *Hanover Protected Wreck : Marine Assessment for Possible De-Designation*. Gloucestershire.

Duhamel du Monceau, Henri-Louis. 1752. *Traité de Construction Des Vaisseaux*. Paris: Charles-Antoine Jombert.

Duivenvoorde, Wendy van. 2010. “The Armament of Australia’s VOC Ships.” (258).

van Duivenvoorde, Wendy. 2015. *Dutch East India Company Shipbuilding. The Archaeological Study of Batavia and Other*

Seventeenth Century VOC Ships. edited by Rachal Foundation nautical archaeological series. College Station, Texas: Texas A&M University Press.

Van Duivenvoorde, Wendy. 2008. “The Batavia Shipwreck: An Archaeological Study of an Early Seventeenth-Century Dutch East Indiaman.” *ProQuest Dissertations and Theses* (August):591.

Van Duivenvoorde, Wendy, Jim Stedman, Kjell Billström, Zofia Anna Stos-Gale, and Michael Mccarthy. 2013. “The Lead Ingots from the Wreck of the Zuiddorp (1712), Western Australia: A Report on Their Provenance and Manufacture.” *International Journal of Nautical Archaeology* 42(1):150–66.

Van Duivenvorde, Wendy. 2015. *Dutch East India Company Shipbuilding: The Archaeological Study of Batavia and Other Seventeenth-Century VOC Ships*. Texas A&M University Press.

Dumas, Frédéric. 1962. *Deep-Water Archaeology*. edited by H. Frost. London: Routledge and Kegan Paul.

Dumas, Frédéric. 1976. *30 Centuries under the Sea*. Crown Publishers.

Dunkley, Mark. 2008. “Stirling Castle, Goodwin Sands, off Kent: Conservation Statement and Management Plan.” (November):28.

Duxbury, A. .. and A. C. Duxbury. 2002. *Fundamentals of Oceanography*. 4th ed. New York: McGraw Hill.

Dyer, K. R. and D. A. Huntley. 1999. “The Origin, Classification and Modelling of Sandbanks and Ridges.” *Continental Shelf Research* 19:1285–1330.

Van Eaton, A. R., J. D. Muirhead, C. N. J. Wilson, and C. Cimarelli. 2012. "Volcanic Hazard from Iceland." *Bulletin of Vulcanology* 74(9):1963–84.

Edina. 2018. "DigiMap." *2018*. Retrieved April 30, 2018 (https://digimap.edina.ac.uk/webhelp/marine/marinedigimaphelp.htm#terms_of_use/licence_agreement.htm).

EEA. 1999. "Environmental Indicators : Typology and Overview." *European Environment Agency* 25(25):19.

EEA. 2018. "Data and Maps." *20182*. Retrieved May 5, 2018 (https://www.eea.europa.eu/data-and-maps).

EH. 2015. "English Heritage Has Changed." *2015*. Retrieved July 21, 2018 (http://www.english-heritage.org.uk/about-us/search-news/english-heritage-has-changed).

Eldersfield, N. 2001. "Sheltering Effects of Offshore Sandbanks: The Goodwin Sands." University of Southampton.

Elkin, Dolores. 2007. "Archaeological Research on HMS Swift: A British Sloop-of-War Lost off Patagonia, Southern Argentina, in 1770." *International Journal of Nautical Archaeology* 36(1):32–58.

Ellwood, Helen. 2011. "Methodology for Creating a Map of Annex I Reef in UK Waters Contents Data Sources." 1–17.

EMODnet. 2016. *EMODnet Thematic Lot N° 3 Seabed Habitats. EMODnet Phase 2 – Final Report Reporting*. Peterborough.

EMODnet. 2018. "Bathymetry. Understanding the Topography of the European Seas." *EMODnet*. Retrieved February 15, 2018 (http://portal.emodnet-bathymetry.eu/).

EMODnet. 2019. "First Harmonised Classification of Submerged Landscape Features and Palaeoenvironmental Indicators for Pan-European Maritime Countries." *2019*. Retrieved April 20, 2019 (http://www.emodnet.eu/first-harmonised-classification-submerged-landscape-features-and-palaeoenvironmental-indicators-pan).

Englert, Anton. 2015. *Large Cargo Ships in Danish Waters 1000-1250: Evidence of Specialised Merchant Seafaring Prior to the Hanseatic Period*. Rooskilde: Viking Ship Museum.

English Heritage. 2010. *Accessing England's Protected Wreck Sites: Guidance Notes for Divers and Archaeologists*. London.

English Heritage. 2012. *MIDAS Heritage – The UK Historic Environment Data Standard, v1.1*. Vol. 1. Swindon.

English Heritage. 2014. *Heritage at Risk. South East*. Guildford.

Eriksson, Niklas. 2013. "Sailing, Sleeping and Eating on Board 17th Centruty ShipsÑ Tapping the Potential of Baltic Sea Shipwrecks with Regard to the Archaeology of Space." in *Interpreting Shipwrecks, Maritime Archaeological Approaches*, edited by J. Adams and J. Rönnby. Southampton: Highfield Press.

Eriksson, Niklas. 2014. "Urbanism Under Sail Urbanism Under Sail." Södertörn University.

Eriksson, Niklas and Johan Rönnby. 2017. "*Mars* (1564): The Initial Archaeological Investigations of a Great 16th-Century Swedish Warship." *International Journal of Nautical Archaeology* 46(1):92–107.

Ernstsen, Verner B., Riko Noormets, Christian Winter, Dierk Hebbeln, Alex Bartholomä, Burg W. Flemming, and Jesper

Bartholdy. 2005. “Development of Subaqueous Barchanoid-Shaped Dunes Due to Lateral Grain Size Variability in a Tidal Inlet Channel of the Danish Wadden Sea.” *Journal of Geophysical Research: Earth Surface* 110(4):1–13.

ESRI. 2018a. “Displaying a DEM with Hillshading.” Retrieved September 2, 2018 (http://desktop.arcgis.com/en/arcmap/10.3/manage-data/raster-and-images/displaying-a-dem-with-hillshading.htm).

ESRI. 2018b. “Renderers Used to Display Raster Data.” *2016*. Retrieved August 11, 2018 (http://desktop.arcgis.com/en/arcmap/10.3/manage-data/raster-and-images/renderers-used-to-display-raster-data.htm).

ESRI. 2018c. “Technical Support. ArcGIS Spatial Analyist.” Retrieved July 31, 2018 (https://support.esri.com/en/other-resources/gis-dictionary/term/9be83193-3047-4a89-a58a-5caf30ece6f3).

ESRI. 2018d. “What Is a Raster?” *2018*. Retrieved April 26, 2018 (https://desktop.arcgis.com/en/arcmap/10.3/manage-data/raster-and-images/what-is-raster-data.htm).

European Union. 2019. “Treaties Office.” *2009*. Retrieved January 21, 2019 (http://ec.europa.eu/world/agreements/prepareCreateTreatiesWorkspace/treatiesGeneralData.do?step=0&redirect=true&treatyId=511).

Evans, Amanda M. and Antony Firth. 2016. “Anthropogenic Impacts of Development-Led Archaeology in an Offshore Context.” Pp. 133–56 in *Site Formation Processes of Submerged Shipwrecks*, edited by M. E. Keith. Geinsville, Florida: Univeristy

Press of Florida.

FARO. 2019. “FARO SCANARM.” *2019*. Retrieved (https://www.faro.com/en-gb/products/3d-manufacturing/faro-scanarm/?gclid=Cj0KCQjwla7nBRDxARIsADll0kCgtLd_LQZ3dstkdqxIH1hQcaHxQQjslBHGcMT8tHLrPzItZllNnTgaAvg3EALw_wcB).

Fearns, P. R. C., W. Klonowski, R. C. Babcock, P. England, and J. Phillips. 2011. “Shallow Water Substrate Mapping Using Hyperspectral Remote Sensing.” *Continental Shelf Research* 31(12):1249–59.

Fernández-Montblanc, T., R. Quinn, A. Izquierdo, and M. Bethencourt. 2016. “Evolution of a Shallow Water Wave-Dominated Shipwreck Site: Fougueux (1805), Gulf of Cadiz.” *Geoarchaeology* 31(6):487–505.

Ferrari, Ben. 1994. “Physical, Biological and Cultural Factors Influencing the Formation, Stabilisation and Protection of Archaeological Deposits in U.K. Coastal Waters.” University of St Andrews.

Ferrari, Ben and Jonathan Adams. 1990. “Biogenic Modifications of Marine Sediments and Their Influence on Archaeological Material.” *International Journal of Nautical Archaeology* 19(2):139–51.

Fincham, Jon. 1851. *A History of Naval Architecture to Which Is Prefixed an Introductory Dissertation on the Aplication of Mathematical Science to the Art of Naval Construction.* London: Whittaker and Co.

Firth, Antony. 2018. *Managing Shipwrecks*. London: Fjordr Limited forHonor Frost Foundation.

Flener, Claude, Matti Vaaja, Anttoni Jaakkola, Anssi Krooks, Harri Kaartinen, Antero Kukko, Elina Kasvi, Hannu Hyyppa, Juha Hyyppa, and Petteri Alho. 2013. “Seamless Mapping of River Channels at High Resolution Using.” *Remote Sensing* 5:6382–6407.

Ford, Ben, Carrie Sowden, Katherine Farnsworth, and Scott Harris. 2016. “Coastal and Inland Geologic and Geomorphic Processes.” Pp. 17–44 in *Site Formation Processes of Submerged Shipwrecks*, edited by M. E. Keith. Geinsville, Florida: Univeristy Press of Florida.

Forster, William a and Kenneth B. Higgs. 1973. “The Kennemerland, 1971. An Interim Report.” *IJNA* 291–300.

Friel, I. 1993. “Henry V’s Grace Dieu and the Wreck in the R. Hamble near Bursledon, Hampshire.” *Ijna* 22(1):3.

Frost, Honor. 1973. “First Season of Excavation on the Punic Wreck in Sicily.” *The Journal of Nautical Archaeology and Underwater Exploration* (2.1):33–49.

Gaffney, Vincent, Kenneth Thomson, Simon Fitch, Mark Bunch, Simon Holford, Kate Briggs, David Smith, Ben Gearey, Tom Hill, Andy Howard, and Christina Jolliffee. 2007. *Mapping Doggerland. The Mesolithic Landscapes of the Southern North Sea*. Vol. 37. edited by V. Gaffney, K. Thomson, and S. Fitch. Oxford: Archaeopress Archaeology.

Galeazzi, Fabrizio. 2016. “Towards the Definition of Best 3D Practices in Archaeology: Assessing 3D Documentation Techniques for Intra-Site Data Recording.” *Journal of Cultural Heritage* 17:159–69.

Garrow, Duncan and Fraser Sturt. 2019. "Neolithic Crannogs: Rethinking Settlement, Monumentality and Deposition in the Outer Hebrides and Beyond." *Antiquity* 93(369):664–84.

Gawronski, J. H. G. 1990. "The Amsterdam Project." *International Journal of Nautical Archaeology* 19(1):53–61.

Gawronski, J. H. G. 2017. "The Wreck of the Amsterdam (1749): Archaeology of European Economy in the Eighteenth Century." Pp. 251–60 in *Atti del convegno = proceedings: 2nd convegno nazionale: Cultura navale e maritima: transire mare, 22-23 Settembre 2016*, edited by M. C. Morozzo della Rocca and F. Tiboni. Genova: Universita degli Studi.

Gawronski, Jerzy, Ranjith Jayasena, and Thijs Terhorst. 2017. *Oostenburg : Woningen En Stadsschuitenmakerswerf*. Amsterdam.

Gawronski, Jerzy, Bas Keist, and Odilia Stokvis-van Boetzelaer. 1992. *Hollandia Compendium: Contribution to the History, Archeology, Classification and Lexicography of a 150 Ft. Dutch East Indiaman (1740-1750)*. Amsterdam: Rijksmusseum & Elsevier Science Ltd.

Gibbins, David. 1990. "Analytical Approaches in Maritime Archaeology: A Mediterranean Perspective." *Antiquity* 64(243):376–389.

Gibbs, Martin. 2006. "Cultural Site Formation Processes in Maritime Archaeology: Disaster Response, Salvage and Muckelroy 30 Years On." *International Journal of Nautical Archaeology* 35(1):4–19.

Gibbs, Martin and Brad Duncan. 2016. "Cultural Site Formation Processes." Pp. 179–210 in *Site Formation Processes of*

Submerged Shipwrecks, edited by M. E. Keith. Geinsville, Florida: Univeristy Press of Florida.

Google. 2019. “Google Earth Engine.” *2019*. Retrieved March 27, 2019 (https://earthengine.google.com/).

GoPro. 2018. “GoPro Hero4 Black.” Retrieved February 19, 2018 (https://shop.gopro.com/EMEA/refurbished/refurbished-hero4-black/CHDNH-B11.html).

Gould, Richard. 2000. *Archaeology and the Social History of Ships.* Cambridge: Cambridge Univeristy Press.

Government of Canada. 2018. “1970-71-72, c. 36, Sch. III. Units of Measurement To Describe Certain Land in Quebec.” Retrieved July 2, 2018 (http://laws-lois.justice.gc.ca/eng/acts/W-6/20030101/P1TT3xt3.html?wbdisable=true).

Grant, Iain. 1995. *The H.M.S. Hazardous Project Site Report .* East Witterings.

Grant, Iain. 1996. *The Hazardous Project Site Report - October 1996*. East Witterings.

Grant, Iain. 1997. *The Hazardous Project Site Report - October 1997*. East Witterings.

Grant, Iain. 1998. *The Hazardous Project Site Report - October 1998*. East Witterings.

Grant, Iain. 1999. *The Hazardous Project Site Report - October 1999*. East Witterings.

Grant, Iain. 2000. *The Hazardous Project Site Report - October 2000* . East Witterings.

Grant, Iain. 2001. *The Hazardous Project Site Report - October 2001*. East Witterings.

Grant, Iain. 2002. *The Hazardous Project Site Report - October 2002.* East Witterings.

Grant, Iain. 2003. *The Hazardous Project Site Report - October 2003*. East Witterings.

Grant, Iain. 2004. *The Hazardous Project Site Report - October 2004*. East Witterings.

Grant, Iain. 2005. *The Hazardous Project Site Report - October 2005*. East Witterings.

Grant, Iain. 2006. *The Warship Hazardous Project Site Report - October 2006*. East Witterings.

Grant, Iain. 2007. *The Warship Hazardous Project Site Report - October 2007 .* East Witterings.

Grant, Iain. 2008. *The Warship Hazardous Project Site Report - October 2008 .* East Witterings.

Grant, Iain. 2009. *The Warship Hazardous Project Site Report - October 2009 .* East Witterings.

Grant, Iain. 2010. *The Warship Hazardous Project Site Report - October 2010*. East Witterings.

Grant, Iain. 2011. *The Warship Hazardous Project Site Report*. East Witterings.

Grant, Iain. 2012. *The Warship Hazardous Project Site Report*. East

Witterings.

Grant, Iain. 2013. *The Warship Hazardous Project Site Report*. East Witterings.

Grant, Iain. 2014. *The Warship Hazardous Project Site Report*. East Witterings.

Grant, Iain. 2015. *The Warship Hazardous Project Site Report*. East Witterings.

Grant, Iain. 2016. *The Warship Hazardous Project Site Report. November 2016.* East Witterings.

Gray, Scott. 2016. “High Resolution 3D Visualizations Using Underwater Laser Scanning.”

Green, Jeremy N. 1973. “The Wreck of the Dutch East Indiaman the Vergulde Draeck, 1656.” *International Journal of Nautical Archaeology* 2(2):267–89.

Green, Jeromy. 2009. *Maritime Archaeology: A Technical Handbook, Second Edition*. New York: Routledge.

Gregory, D. J. 2012. “Development of Tools and Techniques to Survey, Assess, Stabilise, Monitor and Preserve Underwater Archaeological Sites: Sasmap.” *International Journal of Heritage in the Digital Era* 1(1_suppl):367–71.

Gregory, D. J. 2015. “Development of Tools and Techniques to Survey, Assess, Stabilise, Monitor and Preserve Underwater Archaeological Sites: Sasmap.” *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives* 40(5W7):173–77.

Gregory, David and Martijn Manders. 2011. “In-Situ Preservation of a Wreck Site.” Pp. 107–27 in *Wreck Project: Decay and Protection of Archaeological Wooden Shipwrecks*, edited by C. G. Björdal and D. Gregory. Oxford: Information Press.

Grenier, Robert. 2006. “The Annex: Archaeology and the UNESCO Convention 2001.” P. 110 in *Finishing the Interrupted Voyage: Papers of the UNESCO Asia-Pacific Workshop on the 2001 Convention on the Protection of the Underwater Cultural Heritage*, edited by L. Prott. Institute of Art and Law.

Grøn, O., L. O. Boldreel, D. Cvikel, Y. Kahanov, E. Galili, J. P. Hermand, D. Nævestad, and M. Reitan. 2015. “Detection and Mapping of Shipwrecks Embedded in Sea-Floor Sediments.” *Journal of Archaeological Science: Reports* 4(February 2018):242–51.

Van Grondelle, Willem-Jan and Els Vermij. 2018. “Verslag van Het Onderzoek Naar de Bemanning van de Rooswijk , Een Bijdrage Aan Project #Rooswijk1740.” 1740:1–25.

Grontmij, B. V. 1973. *West Winner Reclamation Feasibility Study*. Portsmouth.

Gruen, Armin. 1997. “Fundamentals of Videogrammetry — A Review.” *Human Movement Science* 16(2–3):155–87.

Grussenmeyer, P. and et al. 2016. “Basics of Range-Based Modelling Techniques in Cultural Heritage Recording.” in *3D Recording, Documentation and Management of Cultural Heritage.*, edited by E. Stylianidis and F. Remondino. Dunbeath: Whittles.

Grussenmeyer, P., T. Landes, T. Voegtle, and K. Ringle. 2008. “Comparison Methods of Terrestrial Laser Scanning, Photogrammetry and Tacheometry Data for Recording of Cultural Heritage Buildings.” *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XXXVI(May 2014):213–18.

Guérin, Ulrike. 2019. “Legal Protection for Underwater Cultural Heritage.” 33.

Guidi, G. 2014. “Terrestrial Optical Active Sensors - Theory and Applications.” Pp. 37–60 in *3D Recording and Modelling in Archaeology and Cultural Heritage. Theory and Best Practices*, edited by F. Remondino and S. Campana. Oxford: Hadrian Books Ltd.

Gutowski, Martin, Jonathan M. Bull, Justin K. Dix, Timothy J. Henstock, Peter Hogarth, Tom Hiller, Timothy G. Leighton, and Paul R. White. 2008. “Three-Dimensional High-Resolution Acoustic Imaging of the Sub-Seabed.” *Applied Acoustics* 69(5):412–21.

Haala, Norbert and Yahya Alshawabkeh. 2006. “Combining Laser Scanning and Photogrammetry: A Hybrid Approach for Heritage Documentation.” *Vast* (May):163–70.

Hadley, Brian C., Doug C. Marcy, and Steven C. Raber. 2007. *Topographic and Bathymetric Data Considerations : Datums, Datum Conversion Techniques, and Data Integration*.

Halcrow. 2002. *Futurecoast: Research Project to Improve the Understanding of Coastal Evolution over the next Century for the Open Coastline of England and Wales.* Cambridge.

HampshireTelegraph. 1835. “Provincial Occurences. In the Countries of Engalnd, and in Wales, Scotland and Ireland.” *New Monthly Magazine and Literary Journal. Second Part*, June 22, 4.

Haneca, Kristof and Aoife Daly. 2014. "Tree-Rings, Timbers and Trees: A Dendrochronological Survey of the 14th-Century Cog, Doel 1." *International Journal of Nautical Archaeology* 43(1):87–102.

Harris, Edward C. 1979. "The Laws of Archaeological Stratigraphy." *World Archaeology* (1):111–17.

Harris, Edward C. 2002. *Principles of Archaeological Stratigraphy*. Vol. 31. Second Edi. San Diego, CA: Academic Press Inc.

Hawke, Edward. 1990. *The Hawke Papers: A Selection 1743-1771*. edited by R. Mackay. New York: Routledge.

Hazeu, G. W., M. J. Metzger, C. A. Mücher, M. Perez-Soba, C. Renetzeder, and E. Andersen. 2011. "European Environmental Stratifications and Typologies: An Overview." *Agriculture, Ecosystems and Environment* 142(1–2):29–39.

HE. 2017a. *Historic Wreck Sites at Risk: A Risk Managemetn Toolkit*. Swindon.

HE. 2017b. "Protected Wreck Sites at Risk." *2016*. Retrieved October 24, 2017 (https://historicengland.org.uk/advice/heritage-at-risk/archaeology/protected-wreck-sites-at-risk/).

HE. 2018a. *3D Laser Scanning for Heritage. Advice and Guidance on the Use of Laser Scanning in Archaeology and Architecture*. Swindon.

HE. 2018b. "Download Listind Data." *2017*. Retrieved February 1, 2018 (https://historicengland.org.uk/listing/the-list/data-downloads/).

HE. 2018c. “New Evidence Tells a Tale of Smuggling and Reveals Who Was On Board, During Major Shipwreck Excavation.” *2018*. Retrieved August 16, 2018 (https://historicengland.org.uk/whats-new/news/rooswijk-excavation-reveals-new-evidence-of-smuggling-and-crew-identity).

HE. 2018d. “Periods List (Historic England).” *2018*. Retrieved May 5, 2018 (http://heritage-standards.org.uk/wp-content/uploads/2015/08/Periods-List-HE-FISH-WP.pdf).

HE. 2019a. “Heritage Data Standard and Terminology.” Retrieved February 21, 2019 (https://historicengland.org.uk/advice/technical-advice/information-management/data-standards-terminology/).

HE. 2019b. “Protected Wreck Sites.” *2019*. Retrieved February 15, 2019 (https://historicengland.org.uk/advice/planning/consents/protected-wreck-sites/).

HE, RCE, and MSDS Marine Ltd. 2018. “The Rooswijk Wreck. Educational Virtual Dive.” *2018*. Retrieved August 14, 2018 (https://www.cloudtour.tv/rooswijk/information/0_0).

Henderson, Jon C. 1998. “Islets through Time: The Definition, Dating and Distribution of Scottish Crannogs.” *Oxford Journal of Archaeology* 17(2):227–44.

Henderson, Jon C., Oscar Pizarro, Matthew Johnson-Roberson, and Ian Mahon. 2013. “Mapping Submerged Archaeological Sites Using Stereo-Vision Photogrammetry.” *International Journal of*

Nautical Archaeology 42(2):243–56.

Heritage Data. 2019. “FISH.” Retrieved January 22, 2019 (https://www.heritagedata.org/blog/about-heritage-data/fish/).

Hildred, Alexandra. 1990. *Analysis of Iron Gun on Trucked Carriage*.

Hill, J. N. and R. K. Evans. 1972. “A Model for Classification and Typology.” in *Models in Archaeology*.

Historic England. 2017. *Photogrammetric Applications for Cultural Heritage. Guidance for Good Practise*. edited by J. Bedford. Swindon: Historic England.

Historic Environment Scotland. 2016. *Scotland’s Historic Marine Protected Areas 2016*. Edinbrugh.

Historica Canada. 2018. “Ministère de La Marine.” Retrieved July 24, 2018 (https://www.thecanadianencyclopedia.com/en/article/ministere-de-la-marine/).

Hocker, Frederick. 2010. “Mary Rose Your Noblest Shippe: Anatomy of a Tudor Warship. Review.” *International Journal of Nautical Archaelogy* 214-.

Hocker, Frederick. 2011. *Vasa: A Swedish Warship*. Stockolm: Medstoms Bokforlag.

Hocker, Frederick. 2013. “In Details Remembered: Interpreting the Human Component in Shipbuilding.” Pp. 72–84 in *Interpreting Shipwrecks, Maritime Archaeological Approaches*, edited by J. Adams and J. Rönnby. Southampton: Highfield Press.

Hocker, Frederick, Minna Lieno, Riika Alvik, Shaun Wallace, Daniel Zwick, Oscar Tornquist, Niklas Eriksson, Mirja Arnshav, Yvonne Fors, Charlotte Bjordal, Jonathan Adams, and Johan Rönnby. 2013. *Interpreting Shipwrecks. Maritime Archaeological Approaches*. edited by J. Adams and J. Rönnby. Southampton: Highfield Press.

Holland, Sarah. 2002. "Warship Hazardous Prize: Analysis of the Material Culture and Dynamic Environment of an Eroding Shipwreck." University of Southampton.

Holland, Sarah. 2015. "Shipwreck Biographies: An Integrated Methodology for the Re-Investigation and Ongoing Management of Shipwreck Sites of the English Channel." University of Southampton.

Holt, Peter. 1997. "Site: Re-Surveying the Coronation Offshore Site (1691)." Retrieved April 20, 2018 (http://www.3hconsulting.com/sites/SitesCoronation.html).

Holt, Peter. 2010. "Geophysical Investigations of the Cattewater Wreck 1997-2007." *3H Consulting* (August).

Hood, Jon. n.d. "Invincible (1744)."

Van Hove, R. 2005. "De Doelse Kogge(n) Monumenten." *Monumenten, Landschappen En Archeologie* 24(4):50–69.

Hoving, A. .. J. 1988. "A 17th-Century Dutch 134-Foot Pinas , Part 1 by Nicolaes Witsen 1671." *International Journal of Nautical Arcahaeology* 17.3:211–22.

HR Wallingford. 1995. "Pagham Harbour to River Hamble Coastal Strategy Study." P. 134 in *Pagham Harbour to Portsmouth Harbour. Report to Pagham to Hamble Coast Strategy Group*

(Lead Authority: Chichester District Council). Chichester: Chichester District Council.

HR Wallingford. 1997. "East Solent Shoreline Management Plan." in *The Open Coast. Report to East Solent SMP Project Group (Lead Authority: Havant Borough Council).* Havant Borough Council.

HR Wallingford. 2015. *Goodwin Sands Dredging Coastal Impact Study and EIA Wave Modelling*. Wallinford.

HSE. 1997. *Scientific and Archaeological Diving Projects. Diving at Work Regulations 1997. ACOP. L107*. Norwich.

HWTMA. 2006. *Quantifying the Hazardous Threat: An Assessment of Site Monitoring Data and Environmental Data Sets*. Southampton.

HWTMA. 2010. *Solent Marine Heritage Assets: HMS Invincible Report*. Southampton.

HWTMA. 2013. *Heritage Partnership Agreements for the Site of Bouldnor Cliff, Western Solent.* Southampton.

ICOMOS. 1996. "Principles for the Recording of Monuments , Groups of Buildings and Sites (1996)." *11th ICOMOS General Assembly in Sofia, October 1996* (October):49–52.

Ikelite. 2018a. "Underwater Housing for Canon PowerShot S110." Retrieved February 19, 2018 (https://www.ikelite.com/products/underwater-housing-for-canon-powershot-s110).

Ikelite. 2018b. "WD-3 Wide Angle Dome." Retrieved February 19, 2018 (https://www.ikelite.com/products/wd-3-wide-angle-dome).

IMCA. 2012. "Guidance on Subsea Metrology." *Imca S 019* (February):35.

IMCA. 2016. *Guidance on Vessel USBL Systems for Use in Offshore Survey and Positioning Operations (IMCA S 017)*.

Ingelman-Sundberg, Catharina. 1977. "The VOC Ship Zeewijk Lost off the Western Australian Coast in 1727 An Interim Report on the First Survey." *International Journal of Nautical Archaeology* 6(3):225–31.

INON. 2018. "UF-G140 SD." Retrieved February 19, 2018 (http://www.inon.jp/products/gopro/uflg140sd.html).

James, Alison. 2018. *Review of the Virtual Dive Trails Scheme (7374): A Big Splash or a Damp Squib?* Swindon.

James, Alison and Grant Cox. 2017. "Our Heritage beneath the Waves." *Research. Discovery, Innovation and Science in the Historic Environment* (7):11–16.

JNCC. 2007. "British Cenozoic Fossil Fishes Sites. Bracklesham Bay." Pp. 1–7 in *Fossil Fishes of Great Britain*. Vol. 16. Peterborough: Joint Nature Conservation Committee.

JNCC. 2018. "Data Acquisition and Field Survey Methods." *2018*. Retrieved April 25, 2018 (http://jncc.defra.gov.uk/page-3086).

Johnson, Andrew, Allison Fox, Michael Brew, and Laura Hanley. 2013. "Manx Marine Environment Assessment. Historic Environment. Marine & Coastal Historic Environment." 34.

Johnson, Mathew. 2009. *Archaeological Theory: An Introduction.* 2nd ed. Oxford: Wiley-Blackwell.

Johnston, David A. 2014. *Warship Hazardous Prize (1706) a Protected Wreck Site at Risk Case Study and Quantitative Analysis of Dynamic Seabed Movement and Rapid Site*. Vol. 1988. Southampton.

Jones, Benjamin. 2016. "Spatial Accuracy in Underwater Photogrammetry: A Case Study on The HMS Invincible." University of Southampton.

Jones, T., N. Nayling, and P. Tanner. 2013. "Digitally Reconstructing the Newport Medieval Ship: 3D Designs and Dynamic Visualisations for Recreating the Original Hull Form, Loading Factors, Displacement and Sailing Characteristics." Pp. 123–129 in *ACUA Underwater Archaeology Proceedings 2013*.

Jones, Toby. 2009. "The Newport Ship: Her Three Dimensional Digital Recording and Analysis." *Skyllis* 9:36–41.

de Jong, Johan. 2016. "Navigating Through Technology. Technology and the Dutch East India Company VOC in the Eighteenth Century." University of Twente.

Jong, Johan De. 2010. *Standvastigheid & Verwachting. A Historical and Philosophical Inquiry into Standardization and Innovation in Design and Production of the VOC Retourschip during the 18th Century*.

Keith, Donald H. and Joe J. Simmons. 1985. "Analysis of Hull Remains, Ballast, and Artifact Distribution of a 16th-Century Shipwreck, Molasses Reef, British West Indies." *Journal of Field Archaeology* 12(4):411–24.

Keith, Matthew E. and Amanda M. Evans. 2016. "Sediment and Site Formation in the Marine Environment." Pp. 44–69 in *Site Formation Processes of submerged Shipwrecks*, edited by M. E.

Keith. Geinsville, Florida: Univeristy Press of Florida.

Keith, MatthewE., ed. 2016. *Site Formation Processes of Submerged Shipwrecks*. Geinsville, Florida: Univeristy Press of Florida.

Kenyon, N. H. and B. Cooper. 2005. “Sand Banks , Sand Transport and Offshore Wind Farms.” *Strategic Environmental Assessment (SEA)* (May):106.

King, C. A. M. 1972. *Beaches and Coasts*. London: Edward Arlond.

Kirwan, Seán. 2010. “Ireland and the UNESCO Convention on the Protection of the Underwater Cultural Heritage.” *Journal of Maritime Archaeology* 5(2):105–15.

Kist, J. B. 1990. “Integrating Archaeological and Historical Records in Dutch East India Company Research.” *International Journal of Nautical Archaeology and Underwater Exploration* 19(1):49–51.

Klapa, Przemyslaw, Bartosz Mitka, and Mariusz Zygmunt. 2017. “Application of Integrated Photogrammetric and Terrestrial Laser Scanning Data to Cultural Heritage Surveying.” *IOP Conference Series: Earth and Environmental Science* 95(3).

Klonowski, Wojciech M. 2007. “Retrieving Key Benthic Cover Types and Bathymetry from Hyperspectral Imagery.” *Journal of Applied Remote Sensing* 1(1):011505.

Knight, Jon. 1799. “Coast of Hampshire from Portsmouth to Southampton Water with Part of the Isle of Wight. From Cylver Cliff to West Cowes Including Roads of Spithead, St Helens, Stokes Bay.”

Kocabaş, Ufuk. 2015. “The Yenikapi Byzantine-Era Shipwrecks, Istanbul, Turkey: A Preliminary Report and Inventory of the 27 Wrecks Studied by Istanbul University.” *International Journal of Nautical Archaeology* 44(1):5–38.

Koch, Marko and Martin Kaehler. 2009. “Combining 3D Laser-Scanning and Close-Range Photogrammetry - An Approach to Exploit the Strength of Both Methods.” *Computer Applications to Archaeology* 1–7.

Kongsberg. 2018. “Sub-Bottom Profiler, High Resolution.” Retrieved February 15, 2018 (https://www.km.kongsberg.com/ks/web/nokbg0240.nsf/AllWeb/E0788FD1BE34357FC1257C93004ABB49?OpenDocument).

Kulshreshtha, Anuj and Palanisamy Shanmugam. 2015. “Estimation of Secchi Transparency in Turbid Coastal Waters.” *Aquatic Procedia* 4(Icwrcoe):1114–18.

Kumpumäki, Teemu, Pekka Ruusuvuori, Ville Kangasniemi, and Tarmo Lipping. 2015. “Data-Driven Approach to Benthic Cover Type Classification Using Bathymetric Lidar Waveform Analysis.” *Remote Sensing* 7(10):13390–409.

Laan, Adolf van der. n.d. “A Dutch Hekboat, Tacking a Boat.”

Larn, R. and B. Larn. 2002. *Shipwreck Index of the British Isles*. London: Lloyd’s Register.

Larn, Richard and Bridget Larn. 1995. *Shipwreck Index of the British Isles. Volume 2*. London: Loyds Register.

Lavery. 2014. *The Ship of the Line: A History in Ship Models*. Barnsley: Seaforth Publishing.

Lavery, Brian. 1988. *The Royal Navy's First Invincible: The Ship, the Wreck and the Recovery. Invincible Conservations (1744-1758)*. Invincible Conservations (1744-1758) Ltd.

Lavery, Brian. 2009. *Empire of the Seas*. London: Conway.

Lee, Zhong Ping, Shaoling Shang, Chuanmin Hu, Keping Du, Alan Weidemann, Weilin Hou, Junfang Lin, and Gong Lin. 2015. "Secchi Disk Depth: A New Theory and Mechanistic Model for Underwater Visibility." *Remote Sensing of Environment* 169:139–49.

Leino, Minna, Ari T. Ruuskanen, Juha Flinkman, Jussi Kaasinen, Ulla E. Klemelä, Riikka Hietala, and Niko Nappu. 2011. "The Natural Environment of the Shipwreck Vrouw Maria (1771) in the Northern Baltic Sea: An Assessment of Her State of Preservation." *International Journal of Nautical Archaeology* 40(1):133–50.

Long, Dave. 2006. *BGS Detailed Explanation of Seabed Sediment Modified Folk Classification*. London.

Loughman, Emily. 2007. "What Is the Likelihood That the Tin Ingots from the Erme Ingot Site Are of British Bronze Age Date?" Bournmouth University.

Lozano, Jorge. 2001. "Catálogos Nacionales de Patrimonio En Europa: Una Visión de Conjunto." *Proceedings of the Second European Conference Culturtec* 1–16.

Lucas, Gavin. 2011. *Understanding the Archaeological Record*. Cambridge: Cambridge University Press.

Mackintosh, Robert Finlay. 2018. "The 2001 UNESCO Convention on the Protection of the Underwater Cultural Heritage:

Implementation and Effectivness.” University of Southampton.

Magra, Christopher P. 2016. *Poseidon’s Curse. British Naval Impressment and Atlantic Origin of the American Revolution*. London: Cambridge Univeristy Press.

Manders, M.R. & Al-Hamdani, Z. 2011. “Guidelines for Protection of Submerged Wooden Cultural Heritage 2011.”

Mandlburger, Gottfried, Martin Pfennigbauer, Ursula Riegl, Alexander Haring, Martin Wieser, Philipp Glira, and Lukas Winiwarter. 2015. “Complementing Airborne Laser Bathymetry with UAV-Based Lidar for Capturing Alluvial Landscapes.” 9637(October 2015):1–14.

Manzanilla, Linda. 2000. “Posrscript.” Pp. 243–56 in *Cultural Evolution. Contemporary Viewpoints*, edited by G. M. Feinman and L. Manzanilla. New York: Kluwer Academic/Plenum Publishers.

Maritime Archaeology Trust. 2018. “Warship Hazardous.” Retrieved April 6, 2018 (http://www.maritimearchaeologytrust.org/hazardous).

Marsden, Peter. 1972. “The Wreck of the Dutch East Indiaman Amsterdam An Interim Report.” 73–96.

Marsden, Peter. 1974. *The Wreck of the Amsterdam*. London: Hutchinson & Co.

Marsden, Peter. 1976. “The Meresteyn, Wrecked in 1702, near Cape Town, South Africa.” *International Journal of Nautical Archaeology* 5(3):201–19.

Marsden, Peter. 1978. “A Reconstruction of the Treasure of the

Amsterdam and the Hollandia, and Their Significance.” *International Journal of Nautical Archaeology* 7(2):133–48.

Marsden, Peter. 2003. *Sealed by Time: The Loss and Recovery of the Mary Rose*. edited by P. Marsden. Archaeology of the Mary Rose.

Marsden, Peter. 2007. *Guide to the Wreck Site of the “Amsterdam” 1749 at Hastings*. Hastings: the Shipwreck & Coastal Heritage Centre.

Marsden, Peter and David Lyon. 1977. “A Wreck Believed to Be the Warship Anne, Lost in 1690.” *International Journal of Nautical Archaeology* 6(1):9–20.

Martin, Colin. 1975. *Full Fathom Five: Wrecks of the Spanish Armada*. London: Chatto & Windus.

Martin, Colin. 2011. “Wreck-Site Formation Processes.” Pp. 47–67 in *Oxford Handbook of Maritime Archaeology.*, edited by A. Catsambis, B. Ford, and D. Hamilton. New York: Oxford University Press.

Martin, Colin. 2012. “Wreck-Site Formation Processes.” *The Oxford Handbook of Maritime Archaeology* (November 2017):1–22.

Martin, Colin. 2014. “Wreck Site Formation Processes.” Pp. 7916–20 in *Encyclopedia of Global Archaeology*, edited by C. Smith. New York, NY: Springer.

Martin, Colin. 2017. *A Cromwellian Warship Wrecked off Duart Castle, Mull, Scotland, in 1653*. Edinbrugh: Society of Antiquaries of Scotland.

Martin, Colin J. M. 1972. “El Gran Grifon. An Armada Wreck on Fair

Isle." *International Journal of Nautical Archaeology* 1(1):59–71.

Martin, Colin J. M. 1978. "The Dartmouth, a British Frigate Wrecked off Mull, 1690." 1687:29–58.

Martin, Colin J. M. 1979. "La Trinidad Valencera: An Armada Invasion Transport Lost off Donegal Interim Site Report, 1971–76." *International Journal of Nautical Archaeology* 8(1):13–38.

Martin, Colin J. M. 2005. "The Adelaar: A Dutch East-Indiaman Wrecked in 1728 off Barra, Outer Hebrides, Scotland." *International Journal of Nautical Archaeology* 34(2):179–210.

Martin, Louise. 2008. *The Wreck of the Anne, Pett Level, East Sussex. Report on Geophysical Survey*. Portsmouth.

Marx, Robert F. 1991. *The History of Underwater Exploration*. New York: Dover Publications Inc.

Mary Rose Museum. 2018. "Salvaging the Mary Rose – 1836-1843." *2014*. Retrieved March 10, 2018 (https://maryrose.org/blog/historical/museum-blogger/salvaging-the-mary-rose-1836-1843/).

MAST. 2017. "Coronation Shipwreck Virtual 3D Trail." Retrieved April 20, 2018 (http://www.thisismast.org/projects/coronation-3d-virtual-trail.html).

MAT. 2008. "Invincible, Interactive Site-Viewer." *MAT*. Retrieved February 18, 2018 (http://www.maritimearchaeologytrust.org/mapguide/maps/invincible/main.php).

MAT. 2018. "HMT Arfon (1917), Stern and Propeller." *2017*. Retrieved April 23, 2018 (https://skfb.ly/WyHD).

MAT & Artas Media. 2018. “The Wreck of the HMT Arfon.” *2017*. Retrieved April 23, 2018 (https://www.cloudtour.tv/arfon).

Maté-González, Miguel Ángel, Julia Aramendi, Diego González-Aguilera, and José Yravedra. 2017. “Statistical Comparison between Low-Cost Methods for 3D Characterization of Cut-Marks on Bones.” *Remote Sensing* 9(9).

Mattei, Gaia and Francesco Giordano. 2015. “Integrated Geophysical Research of Bourbonic Shipwrecks Sunk in the Gulf of Naples in 1799.” *Journal of Archaeological Science: Reports* 1:64–72.

MCA. 2013. *UK Civil Hydrography Programme Survey Specification*.

MCA. 2014. “The Workboat Code - Industry Working Group Technical Standard.”

McBreen, Fionnuala, Natalie Askew, Andrew Cameron, David Connor, Helen Ellwood, and Anita Carter. 2011. *UK SeaMap 2010. Predictive Mapping of Seabed Habitats in UK Waters*. Peterborough.

McCarthy, John and Jonathan Benjamin. 2014. “Multi-Image Photogrammetry for Underwater Archaeological Site Recording: An Accessible, Diver-Based Approach.” *Journal of Maritime Archaeology* 9(1):95–114.

McCarthy, John, Jonathan Benjamon, Trevor Winston, and Wendy van Duivenvoorde. 2019. “The Rise of 3D in Maritime Archaeology.” Pp. 1–11 in *3D Recording and Interpretation for Maritime Archaeology*, edited by J. K. McCarthy. Cham, Switzerland: Springer Open.

McCarthy, Michael. 2001. *Iron and Steamship Archaeology. Success* *and Failure on the SS Xantho*. New York: Springer.

McElvogue, Douglas. 2015. *Tudor Warship Mary Rose (Anatomy of The Ship).* London: Conway. Bloomsbery Publishing Plc.

McGrail, S. 2001. *Boats of the World: From the Stone Age to Medieval Times*. Oxford: Oxford University Press.

Mcgrail, Sean. 1985. "Towards a Classification of Water Transport." *World Archaeology* 16(3):289–303.

Mckee, Alexander. 1972. "The Influence of British Naval Strategy on Ship Design: 400–1850." Pp. 229–230 in *History of Searfaring Based on Underwater Archaeology*, edited by G. F. Bas. London: Thames and Hudson.

Mckee, Alexander. 1982. *How We Found the Mary Rose*. Souvenir Pree Ltd.

McKee, Eric. 1972. *Clenched Lap or Clinker: An Appreciation of a Boat Building Technique*. Greenwich, London: National Maritime Museum.

McKee, Eric. 1983. *Working Boats of Britain. Their Shape and Puropse*. London: Conway Maritime Press.

Mckenzee, Murdoch. 1786. "St Helens Road, Spithead, Portsmouth and Langstone."

McPherron, Shannon P., Tim Gernat, and Jean Jacques Hublin. 2009. "Structured Light Scanning for High-Resolution Documentation of in Situ Archaeological Finds." *Journal of Archaeological Science* 36(1):19–24.

van der Meer, Freek D., Harald M. A. van der Werff, Frank J. A. van

Ruitenbeek, Chris A. Hecker, Wim H. Bakker, Marleen F. Noomen, Mark van der Meijde, E. John M. Carranza, J. Boudewijn de Smeth, and Tsehaie Woldai. 2012. "Multi- and Hyperspectral Geologic Remote Sensing: A Review." *International Journal of Applied Earth Observation and Geoinformation* 14(1):112–28.

Merret-Jones, Michaela. 2000. "The Effect of Swage Enrichment upon the Integrity of the Fabric of Marine Sites of Archaeological Importance." University of Surrey.

Merton, Robert k. 1968. "On Sociological Theories of the Middle Range." in *Social Theory and Social Structure*. New York: The Free Press.

Merton, Robert K. 1949. "On Sociological Theories of the Middle Range." Pp. 39–53 in *Social Theory and Social Structure*. New York, NY: Simon & Shuster.

Middleton, Arthur Pierce. 1946. "The Chesapeake Convoy System." *The William and Mary Quarterly* 3(2):182–207.

Miles, James Edward. 2017. "The Potential of Structural Analysis in Archaeological Simulation and Interpretation: A Case Study of Medieval Winchester Cathedral Precinct." University of Southampton.

Ministry of Defence. 2010. *Overseas Territories The Ministry of Defence's Contribution*. London.

Ministry of the Environment, E-Commerce, Telecommunications and. 2001. *Bermuda Historic Wrecks Act 2001*. Hamilton.

MOD. 2014. *Protection and Management of Historic Military Wrecks Outside UK Territorial Waters. Guidance on How*

Existing Policies and Legislation Apply to Historic Military Wreck Sites.

MOD. 2017. *The Protection of Military Remains Act 1986 (Designation of Vessels and Controlled Sites) Order 2017*. Vol. 1986. United Kingdom.

MOD. 2018. “Ships.” Retrieved May 15, 2018 (https://www.royalnavy.mod.uk/the-equipment/ships).

Monkhouse, F. J. 1970. *A Dictionary of Geography*. Chicago: Aldine Pub Co.

Morris, R. 1979. *HMS Colossus: The Story of the Salvage of the Hamilton Treasures*. London: Hutchinson & Co.

Morris, Roland. 1969. *Island Treasure: The Search for Sir Cloudesley Shovell’s Flagship “Association.”* London: Hutchinson & Co.

Mostafa Abdel-Bary, Ebarhim. 2013. “3D Laser Scanners’ Techniques Overview.” *International Journal of Science and Research* 14611(10):2319–7064.

Mrozowski, Stephen A. 1999. “Colonization and the Commodification of Nature.” *International Journal of Historical Archaeology* 3(3):153–66.

MSDS Marine Ltd. 2017. “RT @MSDSMarine.” *17th Nov 2017*. Retrieved November 17, 2017 (https://twitter.com/msdsmarine?lang=en).

MSDS Marine Ltd. 2018. “Rooswijk 1740 Excavaiton.” Retrieved April 6, 2018 (https://msdsmarine.com/rooswijk1740-excavation/).

MSDS Marine Ltd & Artas Media. 2018a. “The U8 Virtual Tour.” *2018*. Retrieved (https://www.cloudtour.tv/u8/information/0_7).

MSDS Marine Ltd & Artas Media. 2018b. “U8 Virtual Tour.” *2017*. Retrieved March 23, 2018 (https://www.cloudtour.tv/u8/).

Muckelroy, Keith. 1975. “A Systematic Approach to the Investigation of Scattered Wreck Sites.” *International Journal of Nautical Archaeology* 4(2):173–90.

Muckelroy, Keith. 1976a. “The Integration of Historical and Archaeological Data Concerning an Historic Wreck Site: The ‘Kennemer- Land.’” *World Archaeology*.

Muckelroy, Keith. 1976b. “The Integration of Historical and Archaeological Data Concerning an Historic Wreck Site: The ‘Kennemerland.’” *World Archaeology* 7(3):280–90.

Muckelroy, Keith. 1977. “Historic Wreck Sites in Britain and Their Environments.” *International Journal of Nautical Archaeology* (1911):47–57.

Muckelroy, Keith. 1978a. *Maritime Archaeology*. Cambridge: Cambridge Univeristy Press.

Muckelroy, Keith. 1978b. “The Archaeology of Shipwrecks.” *Maritime Archaeology* 267–90.

Murphy, Larry. 1997. “Site Formation Processes.” Pp. 386–88 in *Encyclopedia of Underwater and Maritime Archaeology*, edited by J. P. Delgado. New Haven: Yale University Press.

Murray, Cristian, Damián Vainstub, Martijn Manders, and Ricardo Bastida. 2003. “El Naufragio Del Hoorn -1615- Prospecciones

Costeras y Subacuáticas En La Ría Deseado (Santa Cruz - Argentina).” Pp. 351–56 in *Arqueologia de Fuego-Patagonia: levantando piedras, desenterrando huesos ... y develando arcanos. 351-355.*, edited by F. Morello, M. Martinic, A. Prieto, and G. Bahamonde. Punta Arenas: CEQUA.

Murray, Michael C., Fraser Sturt, Graeme Earl, and Lucy Blue. 2017. “Recording Shipwrecks at the Speed of Light Underwater Laser Scanning Compared to Photogrammetry in Maritime Archaeology (Case Study Phase III / Mandalay Shipwreck / Biscayne National Park).” (January):2017.

Mynd, J., John Boydell, and Robert Short. 1747. “To the Honble Peter Warren...This Plate Is Most Humbly Dedicated...An Exact View of His Majesty’s Ship Invincible, of 74 Guns, One of the Six French Men of War Taken the 3rd May 1747 by the British Fleet...”

NA. 2018. “Ships Wrecked or Sunk.” *The National Archives*. Retrieved February 15, 2018 (http://www.nationalarchives.gov.uk/help-with-your-research/research-guides/ships-wrecked-sunk/).

Napolitano, Rebecca K., George Scherer, and Branko Glisic. 2018. “Virtual Tours and Informational Modeling for Conservation of Cultural Heritage Sites.” *Journal of Cultural Heritage* 29:123–29.

NAS. 2018. “NAS. About.” Retrieved July 27, 2018 (https://www.nauticalarchaeologysociety.org/content/about).

NAS & 3Deep. n.d. “Holland 5 Submarine Diver Trail.” *2017*. Retrieved April 22, 2018 (http://www.nauticalarchaeologysociety.org/content/holland-5-submarine-diver-trail).

National Geographic. 2017. “Shipwrecks of the Black Sea: Finding an Underwater Graveyard.” *March/April*.

National Geospatial-Intelligence Agency. 2018. “Prototype Global Shoreline Data (Satellite Derived High Water Line Data).” *NGA*. Retrieved February 14, 2018 (https://dnc.nga.mil/PrototypeGSD.php).

Nayegandhi, Amar. 2006. “Green , Waveform Lidar in Topo-Bathy Mapping – Principles and Applications.”

Nayling, Nigel. 2010. *The Swash Channel Wreck, Dorset Tree-Ring Analysis of Ship Timbers*. Lampeter.

Nayling, Nigel and Toby Jones. 2014. *The Newport Medieval Ship, Wales, United Kingdom*. Vol. 43.

NCEI. 2017. “Shoreline / Coastline Resources.” *Information, National Centers for Environmental*. Retrieved November 8, 2017 (https://www.ngdc.noaa.gov/mgg/shorelines/).

Needham, Stuart, David Parham, and Catherine J. Frieman. 2013. *Claimed by the Sea: Salcombe, Langdon Bay, and Other Marine Finds of the Bronze Age*. CBA Resear. York: Council for British Archaeology.

Nesteroff, W. D. 1972. “Geological Aspects of Marine Sites.” Pp. 175–84 in *Underwater Archaeology: A Nascent Discipline*. Paris: UNESCO.

New Forest District Council. 2018. “North Solent Shoreline Managment Plan.” Retrieved February 12, 2018 (http://www.northsolentsmp.co.uk/CHttpHandler.ashx?id=15858&p=0).

Newforest District Council. 2010. “North Solent SMP Appendix C Baseline Process Understanding.” *Response* 1.

Niccolucci, Franco, Paola Ronzino, and Nicola Amico. 2011. “Assessment and Comparison of Metadata Schemas for Architectural.” *Proceedings of CIPA*.

Nijhoff, Martinus. 1979a. *Dutch-Asiatic Shipping in the 17th and 18th Centuries, Volume II, Outward-Bound Voyages from the Netherlands to Asia and the Cape (1595-1794).* edited by J. R. Brujin, F. . Gaastra, and I. Schöffer. New York: Springer.

Nijhoff, Martinus. 1979b. *Dutch-Asiatic Shipping in the 17th and 18th Centuries: Homeward-Bound Voyages from Asia and the Cape to the Netherlands (1597-1795)*. edited by J. R. Brujin, F. . Gaastra, and I. Schöffer. New York: Springer.

Nikolakopoulos, Konstantinos G., Konstantina Soura, Ioannis K. Koukouvelas, and Nikolaos G. Argyropoulos. 2017. “UAV vs Classical Aerial Photogrammetry for Archaeological Studies.” *Journal of Archaeological Science: Reports* 14:758–73.

Nikon. 2018a. “AF-S NIKKOR 14-24mm f/2.8G ED.” Retrieved February 19, 2018 (https://www.europe-nikon.com/en_GB/product/nikkor-lenses/auto-focus-lenses/fx/zoom/af-s-nikkor-14-24mm-f-2-8g-ed#tech_specs).

Nikon. 2018b. “AF-S NIKKOR 20mm f/1.8G ED.” Retrieved February 19, 2018 (https://www.europe-nikon.com/en_GB/product/nikkor-lenses/auto-focus-lenses/fx/single-focal-length/af-s-nikkor-20mm-f-1-8g-ed).

Nikon. 2018c. “Differences between RAW, TIFF, and JPG File Formats?” *2018*. Retrieved April 25, 2018 (https://www.nikonimgsupport.com/na/NSG_article?articleNo

=000025588&configured=1&lang=en_SG).

Nikon. 2018d. “Nikon D610.” Retrieved February 19, 2018 (https://www.nikonusa.com/en/nikon-products/product/dslr-cameras/d610.html#tab-ProductDetail-ProductTabs-TechSpecs).

Nikon. 2018e. “Nikon D800.” Retrieved February 19, 2018 (https://www.nikonusa.com/en/nikon-products/product-archive/dslr-cameras/d800.html).

NOAA. 2018a. “Currents.” *2018*. Retrieved July 31, 2018 (https://oceanservice.noaa.gov/education/kits/currents/02tidal1.html).

NOAA. 2018b. “Currents.” *2017*. Retrieved May 9, 2018 (https://oceanservice.noaa.gov/education/kits/currents/03coastal1.html).

NOAA. 2018c. “The Open Ocean.” Retrieved May 31, 2018 (https://coast.noaa.gov/data/SEAMedia/Presentations/PDFs/Grade 3 Unit 2 Lesson 1 The Open Ocean.pdf).

NOAA. 2018d. “What Are Mesophotic Coral Ecosystems?” *2018*. Retrieved April 25, 2018 (https://oceanservice.noaa.gov/facts/mesophotic.html).

NOAA. 2018e. “What Are Spring and Neap Tides?” Retrieved July 30, 2018 (https://oceanservice.noaa.gov/facts/springtide.html).

NOAA. 2019. “How Much Water Is in the Ocean?” Retrieved (https://www.un.org/en/events/oceansday/background.shtml).

O’Flanagan, Patrick. 2010. *Port Cities of Atlantic Iberia, c.1500–*

1900. Vol. 36.

O'Shea, John M. 2002. "The Archaeology of Scattered Wreck-Sites: Formation Processes and Shallow Water Archaeology in Western Lake Huron." *International Journal of Nautical Archaeology* 31(2):211–27.

Observatory, Plymouth Coastal. 2018. "LiDAR." *2018*. Retrieved May 18, 2018 (http://southwest.coastalmonitoring.org/our-data/lidar-light-detection-and-ranging/).

Oertling, Thomas J. 1989. "The Molasses Reef Wreck Hull Analysis: Final Report." *International Journal of Nautical Archaeology* 18(3):229–43.

OESEA3. 2014. *Offshore Energy SEA 3: Appendix 1 Environmental Baseline. Appendix 1l: Cultural Heritage*. London.

Oldham, N., M. Palmer, and J. Tyson. 1993. "The Erme Estuary, Devon, Historic Wreck Site, 1991–3." *International Journal of Nautical Archaeology* 22(4):323–30.

Open Archives. 2018. "Jan Daniel Booij, on October 24, 1737 in the Service of the Dutch East India Company." Retrieved August 6, 2018 (https://www.openarch.nl/show.php?archive=ghn&identifier=f95d4736-d97e-4f2c-998f-447df0cf9294&lang=en).

Open Data Unit. 2018. "The Real Map of Ireland." *2018*. Retrieved April 25, 2018 (https://data.gov.ie/dataset/the-real-map-of-ireland).

Orbasil, Aylin and Peter Chowne. 2013. *Underwater Cultural Heritage & Battlefields in Jersey Scoping Study*.

Orser. 2016. *Historical Archaeology*. 3rd ed. New York, NY: Routledge.

Orser, Charles. 1996. *A Historical Archaeology of the Modern World*. New York: Plenum Press.

Orser, Charles E. 2010. “Twenty-First-Century Historical Archaeology.” *Journal of Archaeological Research* 18(December 2009):111–50.

Ortiz-Vázquez, Rodrigo. 2013. “4D Modelling Site Formation Process of the Royal Navy’s First HMS Invincible Wreck Site (1758-2013), East Solent, UK.” University of Southampton.

Owen, Norman. 1987. *HMS Hazardous-Bracklesham Bay, Pre-Disturbance Site Survey. Interim Report, December 1987.* Farham.

Owen, Norman. 1988. “HMS Hazardous Wrecked 1706. Pre-Disturbance Survey Report 1987.” *International Journal of Nautical Archaeology* 17(4):285–93.

Owen, Norman. 1991. “Hazardous 1990-1991 Interim Report.” *International Journal of Nautical Archaeology* 20(4):325–34.

Owen, Norman. 1994. *The Warship Hazardous Project Site Report*. Chichester.

Owen, Norman, Alexander McKee, and Mike Perkins. 1986. *1986 HMS Hazardous – Bracklesham Bay, Pre-Disturbance Site Survey, Interim Report, October 1986.* Farham.

Oxley, Ian and Matthew E. Keith. 2016. “Introduction: Site Formation Processes of Submerged Shipwrecks.” Pp. 1–16 in *Site Formation Processes of submerged Shipwrecks*, edited by

M. E. Keith. Geinsville, Florida: Univeristy Press of Florida.

Oxley, Ian, Matthew Keith, Ben Ford, Carrie Sowden, Katherine Fransworth, Scott Harris, Amanda Evans, Rory Quinn, Robin Saunders, Ruth Plets, Kieran Westley, and Justin Dix. 2016. *Site Formation Processes of Submerged Shipwrecks*. edited by M. E. Keith. University Press of Florida.

Oxman, Bernard H. 1988. "Marine Archaeology and the International Law of the Sea." *Columbia-VLA Journal of Law & the Arts* 12:353–72.

Ozanne, Nicolas. 1752. "Éléments de l'architecture Navale Ou Traité Pratique de La Construction Des Vaisseaux."

Ozsait-Kocabas, I. 2011. "Yenikapı Batıklarının Akdeniz Gemi Yapım Teknolojisindeki Yeri." *Arkeoloji ve Sanat Dergisi* 136:137–148.

Pacheco-Ruiz, Rodrigo, Jonathan Adams, and Felix Pedrotti. 2018. "4D Modelling of Low Visibility Underwater Archaeological Excavations Using Multi-Source Photogrammetry in the Bulgarian Black Sea." *Journal of Archaeological Science* 100(4):120–29.

Pacheco, Rodrigo. 2015. "Maritime Lives in Iron Age Britain."

Palma, Paola. 2005. "Monitoring of Shipwreck Sites." *International Journal of Nautical Archaeology* 34(2):323–31.

Palma, Paola and Dave Parham. 2007. *Swash Channel Wreck; 2006 Season Report*. Bournmouth.

Panich, L. M., T. D. Schneider, and R. S. Byram. 2018. "Finding Mid-19th Century Native Settlements: Cartographic and Archaeological Evidence from Central California." *Journal of*

Field Archaeology 0(0):1–14.

Parham, David. 2005. "The Studland Bay Wreck." in *Society for Historical Archaeology Annual Conference. York (UK)*. York: Bournemouth University.

Parham, David. 2011. "The Swash Channel Wreck." Pp. 103–6 in *ACUA Underwater Archaeology Proceedings*, edited by F. Castro and L. Thomas. Advisory Council on Underwater Archaeology.

Parham, David, Chris Underwood, and Ruth Rhynas Brown. 2013. "British Postal Packet Hanover, 1757: Salvage and Archaeology." *International Journal of Nautical Archaeology* 42(2):403–12.

Parker, Hugh, Nigel Townsend, Mark Sinclair, Paul Seaton, and Fugro Lads. 2012. *European Airborne LiDAR Bathymetry Survey Campaign*. Rome.

Parks Canada. 2007. *The Underwater Archaeology of Red Bay: Basque Shipbuilding and Whaling in the 16th Century. Volume 2*. edited by R. Grenier, B. Marc-André, and S. Willis. Vancouver: Parks Canada.

Parks Canada. 2018. "The Franklin Expedition." Retrieved August 14, 2018 (https://www.pc.gc.ca/en/culture/franklin).

PAS. 2015. *Assessing, Monitoring and Recording a Designated Wreck for Vulnerability: HMS Invincible*. Southampton.

PAS. 2017. *Multi-Beam Surveys of the Designated Wrecks on the Goodwin Sands and the Downs*. Southampton.

PAS. 2018a. "Photogrammetry in the Dark." *2017*. Retrieved April 23, 2018 (https://pascoe-archaeology.com/2017/03/09/photogrammetry-in-the-dark/).

PAS. 2018b. “The London Excavations.” *2017*. Retrieved April 22, 2018 (https://pascoe-archaeology.com/portfolio/the-london/).

PAS & Artas Media. 2016. “The Invincible Wreck.” *CloudTour*. Retrieved February 18, 2018 (https://www.cloudtour.tv/invincible).

PAS & MSDS Marine Ltd. 2018. “Thorness Bay Wreck. Educational Virtual Dive.” *2018*. Retrieved August 18, 2018 (https://www.cloudtour.tv/Thorness).

PAS and Artas Media. 2018. “The Invincible Wreck. Educational Web Tour.” *2016*. Retrieved February 13, 2018 (https://www.cloudtour.tv/invincible).

Pascoe Archaeology. 2018a. “The Hazardous.” Retrieved April 6, 2018 (https://pascoe-archaeology.com/portfolio/the-hazardous/).

Pascoe Archaeology. 2018b. “The Invincible.” *2018*. Retrieved February 21, 2018 (https://pascoe-archaeology.com/portfolio/the-invincible/).

Pascoe, Daniel. 2013. *A New Era of Investigation on the Royal Navy’s First HMS Invincible, Project Report*. Southampton.

Pascoe, Daniel. 2015. *The Mingary Wreck, the Duart Point Wreck and the Dartmouth, Sound of Mull: Archaeological Report*. Cirencester, Milton Keynes, Andover.

Pascoe, Daniel and Carrie Cowan. 2017. *HMS Invincible (1758) Horse Tail, Eastern Solent, Off Portmouth, Conservation Statement and Managment Plan.* Southampton.

Pascoe, Daniel, Mark Mavrogordato, and Angela Middleton. 2014. “A Chain Pump Recovered from the Wreck of the Warship Northumberland (1703).” *International Journal of Nautical Archaeology* n/a-n/a.

Pascoe, Daniel, Mark Mavrogordato, and Angela Middleton. 2015. “A Chain Pump Recovered from the Wreck of the Warship Northumberland (1703).” *International Journal of Nautical Archaeology* 44(1):145–59.

Pascoe, Daniel and Robert Peacock. 2015. “The Wreck of the Warship Northumberland on the Goodwin Sands, England, 1703: An Interim Report.” *International Journal of Nautical Archaeology* 44(1):132–44.

Pecci, Alessandra, Salvador Domínguez-Bella, Mauro Paolo Buonincontri, Domenico Miriello, Raffaella De Luca, Gaetano Di Pasquale, Daniela Cottica, and Dario Bernal - Casasola. 2018. “Combining Residue Analysis of Floors and Ceramics for the Study of Activity Areas at the Garum Shop at Pompeii.” *Archaeological and Anthropological Sciences* 10(2):485–502.

Pieraccini, Massimiliano, Gabriele Guidi, and Carlo Atzeni. 2001. “3D Digitizing of Cultural Heritage.” *Journal of Cultural Heritage* 2(1):63–70.

Pink, Fiona. 2016. “Rapid Coastal Zone Assessment Survey for South West England - South Devon Coast: Results of Phase 1, Component 2 Desk-Based Assessment.” (January).

Plastock. 2018. “Dibond White 9003 Gloss/Matt Sheet.” Retrieved January 23, 2018 (https://www.plastock.co.uk/dibond-white-9003-gloss-matt-sheet).

Plets, R., J. Dix, and R. Bates. 2013. *Marine Geophysics Data*

Acquisition, Processing and Interpretation: Guidance Notes. Swindon.

Plets, Ruth M. K., Justin K. Dix, Jonathan Adams, Jonathan M. Bull, Timothy J. Henstock, Martin Gutowski, and Angus I. Best. 2009. "The Use of a High-Resolution 3D Chirp Sub-Bottom Profiler for the Reconstruction of the Shallow Water Archaeological Site of the Grace Dieu (1439), River Hamble, UK." *Journal of Archaeological Science* 36(2):408–18.

Plets, Ruth M. K., Justin K. Dix, and Angus I. Best. 2008. "Mapping of the Buried Yarmouth Roads Wreck, Isle of Wight, UK, Using a Chirp Sub-Bottom Profiler." *International Journal of Nautical Archaeology* 37(2):360–73.

Plets, Ruth, Rory Quinn, Wes Forsythe, Kieran Westley, Trevor Bell, Sara Benetti, Fergal McGrath, and Rhonda Robinson. 2011. "Using Multibeam Echo-Sounder Data to Identify Shipwreck Sites: Archaeological Assessment of the Joint Irish Bathymetric Survey Data." *International Journal of Nautical Archaeology* 40(1):87–98.

Pol, A. 1986. "For the Convenience of the Indies: Coin Production in 18th-Century Holland for Internal Circulation and for Exportation." Pp. 583–9 in *Proceedings of the 10th International Congress of Numismatics*, edited by I. A. Carradice. London: Raistrick.

Pol, Arent. 1993. *De Schat Van Het Vliegend Hert Compagniesgeld En Smokkelgeld Uit Een VOC Schip.* edited by H. Jacobi and A. Pol. Leiden: Rijksmueum Het Koninklijk Penningkabinet.

Ponterio, Kent. 2006. "Featuring Specie Recovered From the 'Rooswijk' and Part II of the Don Knottle Collection." *C.I.C.F'06*.

Populus, J., M. Vasquez, J. Albrecht, E. Manca, S. Agnesi, Z. Al Hamdani, J. Andersen, A. Annunziatellis, T. Bekkby, A. Bruschi, V. Doncheva, V. Drakopoulou, G. Duncan, R. Inghilesi, C. Kyriakidou, F. Lalli, H. Lillis, G. Mo, M. Muresan, M. Salomidi, D. Sakellariou, M. Simboura, A. Teaca, D. Tezcan, V. Todorova, and L. Tunesi. 2017. *EUSeaMap. A European Broad-Scale Seabed Habitat Map*. Peterborough.

POR/F/11. 1758. "POR Series."

POR /D/13. 1758. "POR Series."

Preece, C. 2004. "Evidence for High Status as Sea: The Church Rocks Wreck." *Proceedings of the Devon Archaeological Society* 62:99–119.

PRO. ADM 1/5297. 1758. "Court Martial Minutes."

PRO ADM 1/5297. 1758a. "Captain Bentley, Court Martial Minutes."

PRO ADM 1/5297. 1758b. "Henry Adkins, Court Martial Minutes."

PRO Adm 51/471. 1758. "Capitan Bentley's Log. PRO Adm 51/471."

PRO ADM 95/15. 1706. "Court Martial Proceedings. Related to the Hazardous Prize."

PRO ADM I/5266. 1706. *Courts Martial Papers.* London: PRO.

PRO WO 47-28. 1715. *Gun Salvage Documentation Letter to Mr. Hooper. 28th July 1715.* London: Public Records Office.

PRO WO 47-29. 1715. *Gun Salvage Documentation Letter to Mr.*

Felton. 10th Feb. 1715/6. London: Public Records Office.

Pugh, David T. 1989. *Tides, Surges and Mean Sea-Level*. Swindon: John Wiley & Sons.

Pulak, Cemal. 2008. “The Uluburun Shipwreck and Late Bronze Age Trade.” Pp. 288–305 in *Beyond Babylon: Art, Trade, and Diplomacy in the Second Millennium B.C.*, edited by J. Aruz, K. Benzeland, and J. M. Evans. New York: Metropolitan Museum of Art.

Quinn, R., J. M. Bull, and J. K. Dix. 1997. “Buried Scour Marks as Indicators of Palaeo-Current Direction at the Mary Rose Wreck Site.” *Marine Geology* 140(3–4):405–13.

Quinn, R., J. M. Bull, J. K. Dix, and J. R. Adams. 1997. “The Mary Rose Site-Geophysical Evidence for Paleo-Scour Marks.” *The International Journal of Nautical Archaeology* 26(1):3–16.

Quinn, Rory. 2006. “The Role of Scour in Shipwreck Site Formation Processes and the Preservation of Wreck-Associated Scour Signatures in the Sedimentary Record - Evidence from Seabed and Sub-Surface Data.” *Journal of Archaeological Science* 33(10):1419–32.

Quinn, Rory, Jonathan Adams, Justin Dix, and Jonathan Bull. 1998. “The Invincible (1758) Site-an Integrated Geophysical Assessment.” *IJNA* 27.2:126–38.

Quinn, Rory and Donal Boland. 2010. “The Role of Time-Lapse Bathymetric Surveys in Assessing Morphological Change at Shipwreck Sites.” *Journal of Archaeological Science* 37(11):2938–46.

Quinn, Rory, Martin Dean, Mark Lawrence, Steve Liscoe, and Donal

Boland. 2005. “Backscatter Responses and Resolution Considerations in Archaeological Side-Scan Sonar Surveys: A Control Experiment.” *Journal of Archaeological Science* 32(8):1252–64.

Quinn, Rory, Wes Forsythe, Colin Breen, Donal Boland, Paul Lane, and Athman Lali Omar. 2007. “Process-Based Models for Port Evolution and Wreck Site Formation at Mombasa, Kenya.” *Journal of Archaeological Science* 34(9):1449–60.

Quinn, Rory, Robin David Saunders, Ruth Plets, Kieran Westley, and Justin K. Dix. 2016. “Marine Scour of Cohesionless Sediments.” Pp. 70–89 in *Site Formation Processes of Submerged Shipwrecks*. Geinsville, Florida: Univeristy Press of Florida.

Quinn, Rory and T. A. G. Smyth. 2017. “Processes and Patterns of Flow , Erosion , and Deposition at Shipwreck Sites: A Computational Fluid Dynamic Simulation.” *Archaeological and Anthropological Sciences*.

R2 Sonic. 2016. “Sonic 2026/2024/2022 Broadband Multibeam Echosounders.” 236.

Raab, L. Mark and Albert C. Goodyear. 1984. “Middle-Range Theory in Archaeology : A Critical Review of Origins and Applications.” *American Antiquity* 4(2):255–68.

Raab, L. Mark and Albert C. Goodyear. 1998. “Middle-Range Theory in Archaeology BT - Maritime Archaeology: A Reader of Substantive and Theoretical Contributions.” Pp. 205–21 in, edited by L. E. Babits and H. Van Tilburg. Boston, MA: Springer US.

Radic Rossi, Irena, Jose Casaban, Kotaro Yamafume, Rodrigo Torres, and Katarina Batur. 2019. “Systematic Photogrammetric

Recording of the Gnalic Shipwreck Hull Remians and Artefacts." Pp. 25–67 in *3D Recording and Interpretation for Maritime Archaeology*, edited by J. K. McCarthy. Cham, Switzerland: Springer Open.

Raoult, Vincent, Peter A. David, Sally F. Dupont, Ciaran P. Mathewson, Samuel J. O'Neill, Nicholas N. Powell, and Jane E. Williamson. 2016. "GoPros^{TM} as an Underwater Photogrammetry Tool for Citizen Science." *PeerJ* 4:e1960.

Rau, M. 2002. "The UNESCO Convention on Underwater Cultural Heritage and the International Law of the Sea." in *6 Max Planck Yearbook of United Nations Law*.

Redknap, M. 1997. "The Cattewater Wreck: A Contribution to 16th Century Maritime Archaeology,." in *Postmedieval Boat and Ship Archaeology BAR International Series 256*, edited by C. O. Cederlund. Oxford: BAR.

Renfrew, Colin and Paul Bahn. 1991. *Archaeology: Theories, Methods, and Practice.* London: Thames and Hudson.

Report, Amended Final. 2011. *Cattewater Wreck Archive Project*.

Reson Inc. 2002. "SeaBat 8125. Ultra High Resolution Focused Multibeam Echosounder System. Operators Manual." (11278).

Reson Inc. 2017. "SeaBat Ultra High Resolution Focused Multibeam Echosounder Sysytem."

Richards, Vicki. 2011. "In Situ Preservation – Application of a Process-Based Approach to the Management of Underwater Cultural Heritage." 45–47.

Rieth, Eric. 2016. *Navires et Construction Navale Au Moyen Âge,* *Archéologie Nautique de La Baltique à La Méditerranée*. Paris: Editions A&J Picard.

Rinaudo, F., F. Chiabrando, A. Lingua, and A. Spanò. 2012. "Archaeological Site Monitoring: Uav Photogrammetry Can Be an Answer." *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XXXIX-B5(September):583–88.

Romijn, R., T. Missiaen, N. Kinneging, G. Blacquière, and S. vd Brenk. 2004. "Archeological Site Investigation Using Very High Resolution 3D Seismics." *European Conference on Underwater Acoustics* 2–7.

Rondelli, Bernardo, Carla Lancelotti, Marco Madella, Alessandra Pecci, Andrea Balbo, Javier Ruiz Pérez, Fernanda Inserra, Charusmita Gadekar, Miquel Ángel Cau Ontiveros, and P. Ajithprasad. 2014. "Anthropic Activity Markers and Spatial Variability: An Ethnoarchaeological Experiment in a Domestic Unit of Northern Gujarat (India)." *Journal of Archaeological Science* 41:482–92.

Rönnby, Johan. 2013. "The Archaeological Interpretation of Shipwrecks." Pp. 9–24 in *Interpreting Shipwrecks, Maritime Archaeological Approaches*, edited by J. Adams and J. Rönnby. Southampton: Highfield Press.

Rosloff, Jay and J. Barto Arnold. 1984. "The Keel of the San Esteban (1554): Continued Analysis." *International Journal of Nautical Archaeology* 13(4):287–96.

Rua, Helena and Pedro Alvito. 2011. "Living the Past: 3D Models, Virtual Reality and Game Engines as Tools for Supporting Archaeology and the Reconstruction of Cultural Heritage - the Case-Study of the Roman Villa of Casal de Freiria." *Journal of*

Archaeological Science 38(12):3296–3308.

Rule, Margaret. 1972. “The Mary Rose. An Interim Report, 1971.” *International Journal of Nautical Archaeology* 1(1):132–35.

Rule, Margaret. 1982. *The Mary Rose. The Excavation and Raising of Henry VIII’s Flagship.* London: Conway Maritime Press.

Rule, Nick. 1989. “The Direct Surey Method (DSM) of Underwater Surey, and Its Application Underwater.” *International Journal of Nautical Arcahaeology* 18(2):157–62.

Ryan, William B. F., Suzanne M. Carbotte, Justin O. Coplan, Suzanne O’Hara, Andrew Melkonian, Robert Arko, Rose Anne Weissel, Vicki Ferrini, Andrew Goodwillie, Frank Nitsche, Juliet Bonczkowski, and Richard Zemsky. 2009. “Global Multi-Resolution Topography Synthesis.” *Geochemistry, Geophysics, Geosystems* 10(3).

Satchell, Julie and Julian Whitewright. 2014. *The Maritime Archaeology of Alum Bay*. Oxford: British Archaeology Reports.

Saucedo, R., J. L. Macías, M. F. Sheridan, M. I. Bursik, and J. C. Komorowski. 2005. “Modeling of Pyroclastic Flows of Colima Volcano, Mexico: Implications for Hazard Assessment.” *Journal of Volcanology and Geothermal Research* 139(1–2):103–15.

SAVANTE. 2017. “CTS-3D Divers Laser Scanner.” Retrieved December 12, 2017 (https://www.savante.co.uk/cts250-divers-laser-scanner).

Schechner, Yoav Y. and Nir Karpel. 2005. “Recovery of Underwater Visibility and Structure by Polarization Analysis.” *IEEE Journal of Oceanic Engineering* 30(3):570–87.

Schenk, Pieter. 1702. “Batavia Gelegen Op Het Eiland Java, Een Beroemde Volkplanting Der Batavere.”

Schenk, T. 2005. “Introduction to Photogrammetry.” *Department of Civil and Environmental Engineering and Geodetic Science, The Ohio State University* 79–95.

Schiffer, Michael. 1987. *Formation Processes of the Archaeological Record*. Albuquerque: University of New Mexico Press.

Schiffer, Michael B. 1972. “Archaeological Context and Systemic Context.” *American Antiquity* 37(02):156–65.

Schiffer, Michael B. 1975. “Archaeology as Behavioral Science.” *American Anthropologist* 77(4):836–48.

Schiffer, Michael and William L. Rathje. 1973. “Efficient Exploration of the Archaeological Record: Penetrating Problems.” Pp. 169–79 in *Research and Theory in Current Archaeology*, edited by C. L. Redman. London: John Wiley and Sons.

Schrödinger, Erwin. 1980. “The Present Situation in Quantum Mechanics: A Translation of Schrödinger’s ‘Cat Paradox Paper’ (Translation of Schrödinger, 1935).” *Proceedings of the American Philosophical Society* 124:152–67.

SCOPAC. 2018a. “East Head to Pagham Harbour, West Sussex.” Retrieved July 30, 2018 (http://www.scopac.org.uk/scopac_sedimentdb/epag/epag.htm).

SCOPAC. 2018b. “Portsmouth Harbour Entrance to Chichester Harbour Entrance.” Retrieved February 20, 2018 (http://www.scopac.org.uk/scopac_sedimentdb/pchi/pchi.htm).

Sea & Sea. 2018a. “FISHEYE DOME PORT 240.” Retrieved February 19, 2018 (https://www.sea-sea.com/diving/camera-housing-accessories/dome-wide-angle-port.html).

Sea & Sea. 2018b. “MDX-D800.” Retrieved February 19, 2018 (http://www.seaandsea.com/pdf_manuals/mdxd800.pdf).

Seasholes, N. S. 1988. “On the Use of Historical Maps.” Pp. 92–118 in *Documentary Archaeology in the New World*, edited by M. C. Beaudry. Cambridge: Cambridge University Press.

Semaan, Lucy and Mohammed Saeed Salama. 2019. “Underwater Photogrammetric Recording at the Site of Anfeh, Lebanon.” Pp. 67–89 in *3D Recording and Interpretation for Maritime Archaeology*, edited by J. K. McCarthy. Cham, Switzerland: Springer Open.

Shaw, Christian. 2015. “Importing NOAA Predicted Tides and Observed Tides into HYPACK ®.” 2–3.

Sheringham, R. N. 1848. “Spithead and Approach from the Eastward.”

Shervais, Katherine and James Dietrich. 2016. *Structure from Motion (SfM) Photogrammetry Data Exploration and Processing Manual*.

Siebke, Inga, Lorenzo Campana, Marianne Ramstein, Anja Furtwängler, Albert Hafner, and Sandra Lösch. 2018. “The Application of Different 3D-Scan-Systems and Photogrammetry at an Excavation — A Neolithic Dolmen from Switzerland.” *Digital Applications in Archaeology and Cultural Heritage* 10(August 2017):1–11.

Simon, Arthi and Palanisamy Shanmugam. 2016. “Estimation of the

Spectral Diffuse Attenuation Coefficient of Downwelling Irradiance in Inland and Coastal Waters from Hyperspectral Remote Sensing Data: Validation with Experimental Data." *International Journal of Applied Earth Observation and Geoinformation* 49:117–25.

Soler, Francisco, Francisco Javier Melero, and Maria Victoria Luzón. 2017. "A Complete 3D Information System for Cultural Heritage Documentation." *Journal of Cultural Heritage* 23:49–57.

SONARDYNE. 2012. *Datasheet SCOUT USBL Transceiver Specifications SCOUT USBL Transceiver*. Plymouth.

St Helena Government. 2017. "Protection of Wrecks and Marine Archaeological Heritage Ordinance 2014. Revised Edition of the Laws, 2017." (November):1–4.

Steffy, Richard. 1975. "Construction Techniques of Ancient Ships." *Naval Engineers Journal* 87.5:85–91.

Steffy, Richard. 1981. "The Serçe Liman Medieval Ship." Pp. 106–13 in *Underwater Archaeology: The Challenge Before Us*, edited by G. Watts. San Marino: San Marino Fathom Eight.

Steffy, Richard. 1985. "The Kyrenia Ship: An Interim Report on Its Hull Construction." *American Journal of Archaeology* 89.1:71–101.

Steffy, Richard. 1994. *Wooden Ship Building and the Interpretation of Shipwrecks*. College Station: Texas A&M University Press.

Steinbacher, F., M. Pfennigbauer, M. Aufleger, and a. Ullrich. 2012. "High Resolution Airborne Shallow Water Mapping." *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XXXIX-B1(September):55–60.

Stenuit, Robert. 1972. *Threasures of the Armada*. David & Charles.

Stewart, David J. 1999. “Formation Processes Affecting Submerged Archaeological Sites: An Overview.” *Geoarchaeology* 14(6):565–87.

Stewart, Joseph. 2011. *Exploring the History of Hyperbaric Chambers, Atmospheric Diving Suits and Manned Submersibles: The Scientist and Machinery*. Bloomington, Indiana: Xlibris Corporation.

Sturt, Fraser, Tyra Standen, Michael Grant, and Justin Dix. 2016. “Determining Potential: Onshore/Offshore Prehistory Project 6918.” 112.

Sulas, Federica and Marco Madella. 2012. “Archaeology at the Micro-Scale: Micromorphology and Phytoliths at a Swahili Stonetown.” *Archaeological and Anthropological Sciences* 4(2):145–59.

Sulpizio, R., L. Capra, D. Sarocchi, R. Saucedo, J. C. Gavilanes-Ruiz, and N. R. Varley. 2010. “Predicting the Block-and-Ash Flow Inundation Areas at Volcán de Colima (Colima, Mexico) Based on the Present Day (February 2010) Status.” *Journal of Volcanology and Geothermal Research* 193(1–2):49–66.

Sundarabalan, Balasubramanian, Palanisamy Shanmugam, and Sadasivan Manjusha. 2013. “Radiative Transfer Modeling of Upwelling Light Field in Coastal Waters.” *Journal of Quantitative Spectroscopy and Radiative Transfer* 121:30–44.

Suziedelyte Visockiene, J., R. Puziene, A. Stanionis, and E. Tumeliene. 2016. “Unmanned Aerial Vehicles for Photogrammetry: Analysis of Orthophoto Images over the Territory of Lithuania.” *International Journal of Aerospace*

Engineering 2016(i).

Tanner, Pat. 2012. “The Application of 3D Laser Scanning for Recording Vessels in the Field.” *Nautical Archaeology Society Newsletter* 1–4.

Tanner, Pat. 2013. “3D Laser Scanning for the Digital Reconstruction and Analysis of a 16th-Century Clinker Built Sailing Vessel.” *ACUA Underwater Archaeology Proceedings* 137–50.

Tanner, Pat and Rodrigo Ortiz. 2019. “Mary Rose.” *2019*. Retrieved April 19, 2019 (https://sketchfab.com/3d-models/mary-rose-316db8d7099b42b28f889aedddc86e9d).

Tchernia, A., P. Pomey, and A. Hesnard. 1978. *Lè Pave Romaine de La Madrague de Giens (Var), Campagnes 1972–1975: Fouilles de l’Institut d’Archeologie Méditerranéenne. Supplément à Gallia 34.* edited by Centre National de la Recherche Scientifique. Paris.

The Crown Estate. 1977. “Protection of Wrecks Ordinance 1976 (Falkland Islands).”

The Crown Estate. 1985. “South Atlantic Territories. The South Georgia and South Sanwich Islands Order 1985.” (449).

The Crown Estate. 1986. “Protection of Military Cultural Heritage Act 1986.” 3(i).

The Crown Estate. 1995. “Merchant Shipping Act 1995.” 310.

The Royal Court of the Island of Guernsey. 1986. “The Wreck and Salvage (Vessels and Aircraft) (Bailiwick of Guernsey).”

The Secretary of State. 1997. *The Diving at Work Regulations 1997*. Vol. 8. United Kingdom.

Thomsen, Mikkel H. and Keith Jarvis. 2000. “The Studland Bay Wreck, Dorset, UK: Hull Analysis.” *International Journal of Nautical Archaeology* 29(1):69–85.

Throckmorton, Peter. 1965. “Wrecks at Methone.” *The Mariner’s Mirror* 51(4):305–20.

Tian-Tuan Shih, Peter, Chen Ya-Hsing, and Chen Jie-Chung. 2014. “Historic Shipwreck Study in Dongsha Atoll with Bathymetric LiDAR.” *Archaeological Prospection* 62(December 2009):139–46.

Tizzard, L., A. R. Bicket, J. Benjamin, and D. De Loecker. 2014. “A Middle Palaeolithic Site in the Southern North Sea: Investigating the Archaeology and Palaeogeography of Area 240.” *Journal of Quaternary Science* 29(7):698–710.

Tomalin, David J., Paul Simpson, and John M. Bingeman. 2000. “Excavation versus Sustainability in Situ: A Conclusion on 25 Years of Archaeological Investigations at Goose Rock, a Designated Historic Wreck-Site at the Needles, Isle of Wight, England.” *International Journal of Nautical Archaeology* 3–42.

Törnblom, Nils. 2010. “Underwater 3D Surface Scanning Using Structured Light.” (December):54.

Tovar-Herrera, Jorge. 2008. “The Reflexive Navigator.” University of Southampton.

Trigger, Bruce. 2006. *A History of Archaeological Thought*. Cambridge: Cambridge Univeristy Press.

Tubbs, C. R. 1999. *Ecology, Conservation and History of the Solent.* Chichester: Packard Publishing Lt.

Tucker, Compton J., Denelle M. Grant, and Jon D. Dykstra. 2004. “NASA’s Global Orthorectified Landsat Data Set.” *Photogrammetric Engineering & Remote Sensing* 70(3):313–22.

Tucker, Scott A. 2017. “Smoke on the Water: An Historical Archaeological Assessment of Maritime Sources of Productivity Change in the Early English Tobacco Trade.” University of Southampton.

Tyson, Jim and Mick Palmer. 2013. *Salcombe/Moor Sand Sites 2013 End of Season Report*.

UKHO. 2013a. *Goodwin Sands. Gull Stream & North Sand Head. Summary Assessment on the Analysis of Routine Resurvey Area GS2 From the 2012 Survey*. Taunton.

UKHO. 2013b. *South Calliper Routine Resurvey Area GS4. From the 2012 Survey*. Taunton.

UKHO. 2015a. *Goodwin Sands. Gull Stream & North Sand Head. Assessment on the Analysis of Routine Resurvey Area GS2 from the 2015 Survey.* Taunton.

UKHO. 2015b. *Goodwin Sands. South Calliper &Goowin Knoll. Sumarry Assessment on the Anlysis of the Focused Routine Resurvey Area Gs4 from the 2015 Survey*. Taunton.

UKHO. 2015c. *Goodwin Sands. South Dans Head. Assessment on the Analysis of Routine Resurvey Area GS1 from the 2015 Survey*. Taunton.

UKHO. 2015d. *Northern Head of South Calliper. Assessment on the*

Analysis of Routine Resurvey Area GS3 from the 2015 Survey. Taunton.

UKHO. 2018a. “Admiratly Total Tide.” Retrieved August 8, 2018 (https://www.admiralty.co.uk/digital-services/admiralty-digital-publications/admiralty-totaltide).

UKHO. 2018b. “UKHO Inspire Portal & Bathymetric DAC.” *2018*. Retrieved April 29, 2018 (http://aws2.caris.com/ukho/mapViewer/map.action).

Uknown. 1709. “‘Warrant Books: January 1709, 11-20.’” Pp. 44–63 in *Calendar of Treasury Books*, edited by W. A. Shaw. London: His Majesty’s Stationery Office.

Uknown. 1725. “Gezicht Op Het Oost-Indisch Zeemagazijn En de VOC-Scheepswerf Op Oostenburg Te Amsterdam.”

Uknown. n.d. “Décor de Poupe (Hazardeux).”

Uknown. n.d. “Superb (Captured 1710).”

UN. 1982a. “Article 303.” Retrieved January 20, 2019 (1982. www.un.org/depts/los/convention_agreements/texts/unclos/UNCLOS-TOC.htm.).

UN. 1982b. “United Nations Convention on the Law of the Sea.” 1–202.

UN. 2019a. “Oceans & Law of the Sea.” *2019*. Retrieved March 18, 2019 (https://www.un.org/depts/los/convention_agreements/convention_overview_convention.htm).

UN. 2019b. “United Nations Treaty Collection.” Retrieved March

18, 2019 (https://treaties.un.org/pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XXI-6&chapter=21&Temp=mtdsg3&clang=_en#EndDec).

UN. 2019c. "World Ocean Day." Retrieved (https://www.un.org/en/events/oceansday/background.shtml).

UNESCO. 2001. "Convention on the Protection of the Underwater Cultural Heritage." 26.

Unger, Richard W. 1978. *Dutch Shipbuilding before 1800.* Assen/Amsterdam: Van Gorcum.

Unger, Richard W. 1995. "The Fluit: Specialist Cargo Vessels 1500 to 1650 (Conway's History of the Ship)." in *Cogs, Caravels and Galleons. The sailing ship 1000-1650*, edited by R. Gardiner and Richard W. Unger. London: Conway Maritime Press.

University of Southampton. 2017. "2,500 Years of Seafaring History Revealed Deep in the Black Sea." *September*. Retrieved January 10, 2018 (https://www.southampton.ac.uk/news/2017/09/black-ships.page).

Unkown. 1758. "Magnanime (Captured 1748)."

Unkown. 1798. "Ajax (1798); Kent (1798) Read."

US Navy. 2016. "US Navy Diving Manual Rev. 7." *Journal of Traumatic Stress* 2(56):991.

USGS. 2019. "Why Is the Ocean Salty?" Retrieved March 18, 2019 (https://www.usgs.gov/special-topic/water-science-school/science/why-ocean-salty?qt-science_center_objects=0#qt-science_center_objects).

USGS National UAS Project Office. 2017. *Unmanned Aircraft Systems Data Post-Processing*.

Valadez-Rocha, V. and L. Ortiz-Lozano. 2013. “Spatial and Temporal Effects of Port Facilities Expansion on the Surface Area of Shallow Coral Reefs.” *Environmental Management* 52(1):250–60.

ValePort. 2018. *Tide Station Tide Guage*. St Peter Port.

Vandiver, Amy. 2002. “Analysis of a Sub-Bottom Sonar Profiler for Surveying Underwater Archaeological Sites.”

Velde, B. 2003. “7.12 - Green Clay Minerals.” Pp. 309–24 in *Treatise on Geochemistry*, edited by Ecole Normale Superieure. Paris: Elsevier.

Ventura, Don. 2012. “Airborne Bathymetric Lidar and Examples of NIOHC-Type Environment IHO Order 1 Specification Coastal Surveys.” (March).

Vereker, F. C. P. 1898. “The Solent- Eastern Part Including Spithead.”

Vermeersch, Jeroen and Kristof Haneca. 2015. “Construction Features of Doel 1, a 14th-Century Cog Found in Flanders.” *International Journal of Nautical Archaeology* 44(1):111–31.

De VOC site. 2018. “Hekboten.” Retrieved August 26, 2018 (https://www.vocsite.nl/schepen/lijsthekboten.html?of=0).

Volent, Zsolt, Geir Johnsen, and Fred Sigernes. 2007. “Kelp Forest

Mapping by Use of Airborne Hyperspectral Imager." *Journal of Applied Remote Sensing* 1(1):011503.

VRA. 2007. "VRA Core 4.0 Outline." *Retrieved January* 25:2008.

WA. 2004. *Wrecks on the Seabed: Assessment, Evaluation and Recording. The Hazardous*. Salisbury.

WA. 2005. *Strategic Enviromental Assessment Sea 6: Irish Sea*. Salisbury.

WA. 2007. *Rooswijk, Goodwin Sands*. Salisbury.

WA. 2015. *Archaeological Services in Relation to Marine Designation Hazardous*. Salisbury.

Wallace, Andrew. 2012. "A Comprehensive Investigation of Lead Seathing from the Emanuel Point Shipwrecks in Pensacola Bay, Florida." University of West Florida.

Wallace, H. 1990. *Sea-Level and Shoreline Between Portsmouth and Pagham for the Past 2,500 Years.* Privately Published by the Author.

Wallingford, H. R. 2000. *Numerical Modelling Studies at East Head, Chichester Harbour. Report EX 4260. Report to ABP Research and Consultancy, Ltd.* Chichester.

Ward, I., P. Larcombe, and P. Veth. 1998. "Towards New Process-Oriented Models for Describing Wreck Disintegration - an Example Using the Pandora Wreck." *Bulletin of the Australian Institute for Maritime Archaeology* 22(January):109–14.

Ward, I., P. Larcombe, and P. Veth. 1999. "A New Process-Based Model for Wreck Site Formation." *Journal of Archaeological*

Science 26:561–70.

Watson, Patty, Steven Le Blanc, and Charles Redman. 1984. *Archeological Explanation: The Scientific Method in Archeology*. New York: Columbia University Press.

Webber, N. B. 1982. *Accretion of Shingle at Eastney Outfall. A Preliminary Appraisal,*.

Weigelt, Ronny, Heike Lippert, Ulf Karsten, and Ralf Bastrop. 2017. "Genetic Population Structure and Demographic History of the Widespread Common Shipworm Teredo Navalis Linnaeus 1758 (Mollusca: Bivalvia: Teredinidae) in European Waters Inferred from Mitochondrial COI Sequence Data." *Frontiers in Marine Science* 4(June):1–12.

Wessex. 2009. *Gull Rock, Off Lunday Island, North Devon*. Salisbury.

Wessex Archaeology. 2003a. *Bonhomme Richard, Filey Bay, North Yorkshire. Designated Site Assessment: Full Report.* Salisbury.

Wessex Archaeology. 2003b. "Stirling Castle, Designated Historic Wreck Site, Desk-Based Assessment." (287786).

Wessex Archaeology. 2004a. *Coronation Offshore, Penlee Point Plymouth. Sedignated Site Assessment: Full Report*. Salisbury.

Wessex Archaeology. 2004b. *Invincible, Solent, Hamphire. Sedignated Site Assessment: Full Report*. Salisbury.

Wessex Archaeology. 2004c. *Iona I, Inner Clyde Estuary, Scotland*. Salisbury.

Wessex Archaeology. 2005a. *Bartholomew Ledges Designated Site Assessment, Salisbury*. Salisbury.

Wessex Archaeology. 2005b. *Iona II, Lundy*. Salisbury.

Wessex Archaeology. 2005c. *Loe Bar, The Lizard, Cornwall. Designated Site Assessment: Full Report*. Salisbury.

Wessex Archaeology. 2006a. *Dunwich Bank, Suffolk. Designated Site Assessment*. Salisbury.

Wessex Archaeology. 2006b. *HMS/m A1, Bracklesham Bay*. Salisbury.

Wessex Archaeology. 2006c. *Restoration, Goodwin Sands.Designated Site Assessment: Archaeological Report*. Salisbury.

Wessex Archaeology. 2006d. *Salcombe Cannon Site, Devon*. Salisbury.

Wessex Archaeology. 2007. *St Anthony. Designated Site Assessment*. Salisbury.

Wessex Archaeology. 2008. *Tearing Ledge, Isles of Scilly. Designated Site Assessment: Archaeological Report*. Salisbury.

Wessex Archaeology. 2009. *HMS/m Holland No.5 English Channel. Designated Site Assessment. Archaeological Report.*

Wessex Archaeology. 2011a. *19th Century Merchant Sailing Ship Off Thorness Bay, Isle of Wight*. Salisbury.

Wessex Archaeology. 2011b. *Unknown Site GAD 8, the Downs, Kent*. Salisbury.

Wessex Archaeology. 2013a. *Admiral Gardner, Goodwin Sands,* *Kent. Designated Site Assessment*. Salisbury.

Wessex Archaeology. 2013b. *Ships and Boats : Prehistory to 1840. Strategic Desk-Based Assessment*. Salisbury.

Wessex Archaeology. 2015. *Archaeological Services in Relation to Marine Designation. HMS Invincible. Marine Geophysical Survey Report.* Salisbury.

Wessex Archaeology. 2017. *UC-70, off Whitby, North Yorkshire, Field Assessment Report for Historic England*. Salisbury.

Wessex Archaeology. 2018. "West Bay." *2008*. Retrieved April 22, 2018 (https://www.wessexarch.co.uk/news/west-bay).

West, Ian. 2018. "Selsey Bill and Bracklesham Bay, Sussex. Geology of the Wessex Coast of Southern England." Retrieved July 28, 2018 (http://www.southampton.ac.uk/~imw/Selsey-Bracklesham.htm).

Whitewright, Julian and Julie Satchell. 2015. *The Archaeology and History of the Flower of Ugie, Wrecked 1852 in the Eastern Solent*. Vol. No 1. Southampton.

WHPPG. 2018a. "Hazardous Dive Trail." Retrieved July 28, 2018 (http://hazardousproject.info/trail.html).

WHPPG. 2018b. "The Hazardous Project." Retrieved April 6, 2018 (http://hazardousproject.info/history1.html).

WHPPG. 2018c. "The Hazardous Project." Retrieved July 15, 2018 (http://hazardousproject.info/history1.html).

Wilkinson, M. W., R. R. Jones, C. E. Woods, S. R. Gilment, K. J. W. McCaffrey, S. Kokkalas, and J. J. Long. 2016. "A Comparison of

Terrestrial Laser Scanning and Structure-Frommotion Photogrammetry as Methods for Digital Outcrop Acquisition." *Geosphere* 12(6):1865–80.

Winfield, Rif. 1997. *The 50-Gun Ship. A Complete History.* Hong Kong: Mercury.

Winfield, Rif. 2010. *British Warships in the Age of Sail 1603-1714: Design, Construction,Careers and Fates*. Barnsley: Seaforth Publishing.

Winfield, Rif. 2014. *British Warships in the Age of Sail 1817-1863. Design, Construction, Careers and Fates*. Yorkshire: Seaforth Publushilng.

Winfield, Rif and Stephen Roberts. 2017. *French Warships in the Age of Sail 1626-1786. Design, Construction, Careers and Fates.* Barnsley: Seaforth Publushilng.

Wrecks Authority. 2012. *Marine Heritage Policy*.

WYTOD. 2013. "Photogrammetric Surveys." Pp. 1–25 in *Engineering and Technical Programs*. Cheyenne, Wyoming: Wyoming Deparment of Transportation.

Yamafune, K., R. Torres, and F. Castro. 2016. "Multi-Image Photogrammetry to Record and Reconstruct Underwater Shipwreck Sites." *Journal of Archaeological Method and Theory*.

Yamafune, K., R. Torres, and F. Castro. 2017. "Multi-Image Photogrammetry to Record and Reconstruct Underwater Shipwreck Sites." *Journal of Archaeological Method and Theory* 24(3):703–25.

Yamafune, Kotaro. 2016. "Using Computer Vision Photogrammetry

(Agisoft Photoscan) to Record and Analyze Underwater Shipwreck Sites." (May).

van der Zanden, Emma H., Christian Levers, Peter H. Verburg, and Tobias Kuemmerle. 2016. "Representing Composition, Spatial Structure and Management Intensity of European Agricultural Landscapes: A New Typology." *Landscape and Urban Planning* 150:36–49.

Zeeuws maritiem muZEEum. 2018. "Vlissingen Museum, Netherlands." Retrieved July 2, 2018 (https://www.muzeeum.nl/nl/programma/offenes-depot).

Zerbini, Andrea. 2018. "Developing a Heritage Database for the Middle East and North Africa." *Journal of Field Archaeology* 43(sup1):S9–18.

Zevenboom, K. M. C. 1956. "DE GEWICHTEN DIE VOOR 1820 TE AMSTERDAM WERDEN GEBRUIKT EN DE IJKMERKEN DIE DAAROP WORDEN AANGETROFFEN." in *Vijf en Veertigste Jaarboek Van Het Genootschap. Amstelodamum*. Amsterdam: J.H. THE BUSSY.

Zhao, Jianhu, Junxia Meng, Hongmei Zhang, and Jun Yan. 2017. "A New Method for Acquisition of High-Resolution Seabed Topography by Matching Seabed Classification Images." *Remote Sensing* 9(12).

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APPENDICES

An Integrated Methodology to Study Site Formation Processes on Submerged Shipwrecks in the 21st c.

By
Rodrigo Ortiz Vázquez

Thesis for the degree of Doctor in Archaeology

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Appendix I. Notes on Classifying Shipwrecks and their Environments (Chapter IV)

1.1 List of Protected Wrecks England

The list contains

- Protected Wreck Number.
- Positioning (easting and northing) in OSGB36 according to HE (HE 2018a).
- Wrecks name.
- Date or launching and wrecking or approximate date for unidentified vessels.
- Seabed Substratum according to Folk's classification (Long 2006).
- Structural remains (extensive, elements or no structure).
- Objects/artefacts (many, some or few).
- Distribution (coherent, scattered ordered or scattered disordered).
- The average depth of site in metres.
- Distance to the coast in kilometres.
- Energy (high, medium or low) according to EMODnet (EMODnet 2018).
- Biozone (littoral, infralittoral, and circalittoral) according to EMODnet (EMODnet 2018).
- Type of vessel if identifiable or possible wrecks names taken from (grey literature, publications and public records.

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	Easting	Northing	Site	Date	Seabed	Structural remains	Objects /Artefacts	Distribution	Average Depth	Distance to the coast	Energy	Biozone	Type
1	476206.3545	94211.2457	*HMS/m A1*	1902-1911	Slightly Gravelly Sand	Extensive	Many	Coherent	12m	4-5km	High	Shallow circalittoral	Submarine (Wessex Archaeology 2006b)
2	435774.7842	90078.71722	Yarmouth Roads	1520c.	Gravel	Elements	Some	Coherent	6m	200-300m	Moderate	Infralittoral	Mediterranean Carrack *Santa Lucia 1576?* (Plets, Dix, and Best 2008)
3	406136.7835	84641.38123	Studland Bay Wreck	Early 1500's	Gravel	Extensive	Many	Coherent	10m	2-3km	Moderate	Shallow circalittoral	Mediterranean Carrack (Parham 2005; Thomsen and Jarvis 2000)
4	167749.9983	13449.99837	Rill Cove	Early 1600's	Sand	No Structure	Many	Scattered*	4m	50-80m	High	Infralittoral	*Unidentified Lizard wreck 1619?* (Camidge 2008, 2013a; Simpson et al. 1977)
5	480670.291	95296.108	*Hazardous*	1698-1706	Gravely Sand	Elements	Many	Scattered Ordered / Scattered Disordered	7m	704-900m	High	Infralittoral	50-Gun Third-rate Man of War (Johnston 2014; Owen 1988; WHPPG 2018)

	Easting	Northing	Site	Date	Seabed	Structural remains	Objects /Artefacts	Distribution	Average Depth	Distance to the coast	Energy	Biozone	Type
6	165643.4473	20616.45671	*Schiedam Prize*	1684	Sand	No Structure	Few	Scattered Ordered	5m	160-200m	High	Infralittoral	Dutch Fluyt (Camidge 2013b)
7	275942.2215	36144.67753	Moor Sand	17th Century	Gravelly Sand	No Structure	Few	Scattered Disordered	12m	250-300	High	Infralittoral	Cannon Site (Tyson and Palmer 2013; Wessex Archaeology 2006d)
8	215058.9973	146170.6603	*Iona II*	1892-1915	Sandy Gravel and Muddy Sand	Extensive	Few	Coherent	24m	1-1.2km	Moderate	Shallow circalittoral	Paddle Steamer (Daykin-iliopoulos and Cousins 2013; Wessex Archaeology 2005a)
9	467932.8197	93770.9835	*HMS Invincible*	1744-1758	Slightly Gravelly Sand	Extensive	Many	Coherent / Scattered Ordered	8m	4.9-6km	Moderate / High	Infralittoral	74-Gun Third-rate man of war (Bingeman 2010; Lavery 1988; PAS 2015; Quinn et al. 1998)
10	214346.1116	146294.8132	Gull Rock	15th-16th c.	Sandy Gravel	No Structure	Few	Scattered Disordered	12m	300-400m	Moderate	Shallow circalittoral	Unknown (Daykin-iliopoulos and Cousins 2013; Wessex 2009)
11	260659.6916	46627.89833	Erme Ingot	Bronze Age	Sandy Gravel	No Structure	Few	Scattered Disordered	3m	200-300m	Low	Infralittoral	Tin Ingots (Bronze age)(Loughman 2007; Pink 2016:26)

	Easting	Northing	Site	Date	Seabed	Structural remains	Objects /Artefacts	Distribution	Average Depth	Distance to the coast	Energy	Biozone	Type
12	577799.9994	108299.9978	*Amsterdam*	1748-1749	Sand	Extensive	Many	Coherent	0m	0	Low	Sublittoral fringe	Dutch East Indiamen (VOC) (Gawronski 1990; Marsden 1972, 1974, 2007)
13	644692.5557	158633.2525	*Stirling Castle*	1679-1703	Slightly Gravelly Sand	Extensive	Many	Coherent	15m	8.2-8.5km	High	Shallow circalittoral	70-gun Third-rate man of war (Astley 2016:162–89; Astley et al. n.d.; Dunkley 2008; Hampshire & Wight Trust for Maritime 2009; PAS 2017:12–13; Wessex Archaeology 2003b)
14	644317.0951	157081.6162	*Restoration*	1678-1703	Slightly Gravelly Sand	Extensive	Many	Coherent	13m	7.2-7.5km	Moderate	Shallow circalittoral	70-gun Third-rate man of war (Wessex Archaeology 2006c)

	Easting	Northing	Site	Date	Seabed	Structural remains	Objects /Artefacts	Distribution	Average Depth	Distance to the coast	Energy	Biozone	Type
15	644318.6277	156802.8051	*Northumberland*	1677-1703	Slightly Gravelly Sand	Extensive	Many	Coherent / Scattered Ordered	17m	7.2-7.4km	Moderate	Shallow circalittoral	70-gun Third-rate man of war (Pascoe, Mavrogordato, and Middleton 2014; Pascoe and Peacock 2015)
16	634143.6175	141761.2973	Langdon Bay	Bronze Age	Sandy Gravel	No Structure	Few	Scattered Disordered	8m	200-300m	Low	Shallow circalittoral	Bronze age site (Muckelroy 1980; Needham, Parham, and Frieman 2013)
17	589766.2116	113624.5238	*Anne*	1687-1690	Sand	Extensive	Many	Coherent	0m	0	Low	Sublittoral fringe	70- gun Third-rate ship of the line (Cowan 2014; Marsden and Lyon 1977; Martin 2008)
18	450125	110567	*Grace Dieu* and the possible site of *Holigost*	1416-1439	Mud	Extensive	Few	Coherent	0m	0	Low	Sublittoral fringe	1400 ton clinker built man-of-war (Clarke et al. 1993; Friel 1993; McGrail 1993; Plets et al. 2009)
19	645135.7949	150436.059	*Admiral Gardner*	1797-1809	Sand	Extensive	Many	Coherent	0m* (burried)	7.2-7.5km	High	Infralittoral	English East Indiamen (Larn and Larn 2002)

	Easting	Northing	Site	Date	Seabed	Structural remains	Objects /Artefacts	Distribution	Average Depth	Distance to the coast	Energy	Biozone	Type
20	80925.71126	6177.017841	Tearing Ledge	1679-1707	Gravelly Sand	Elements	Some	Scattered Disordered	35m	50-100m	High	Infralittoral	70-gun third-rate of 1053 tons (possibly) *Eagle* 1679-1703. (Camidge and Johns 2017; CISMAS 2017; Johns, Larn, and Tapper 2004; Wessex Archaeology 2008)
21	294724.6803	73209.87665	Church Rocks	Post-Medieval	Muddy Sand	No Structure	Some	Scattered Disordered	4m	60-200m	Low	Infralittoral	Possible Venetian Galley (Beltrame, Gelichi, and Miholjek 2014:42; Pink 2016:56)
22	248725.1927	53519.31619	Cattewater	16th c	Gravelly Mud	Elements	Few	Scattered Disordered	3m	140-200m	Moderate	Infralittoral	16th Century vessel (Holt 2010; Mortlock and Redknap 1978; Redknap 1997)

	Easting	Northing	Site	Date	Seabed	Structural remains	Objects /Artefacts	Distribution	Average Depth	Distance to the coast	Energy	Biozone	Type
23	89108.22371	9649.737801	Bartholomew Ledges	16th c	Gravelly Sand	No Structure	Few	Scattered Disordered	12m	600m	High	Infralittoral	*San Bartolome* Possible Spanish Armada wreck (Camidge, Goskar, and James 2017:6,12, 19, 23; Camidge and Johns 2016a)
24	165183.5852	22477.16738	*St Anthony*	1527	Sand	No Structure	Some	Scattered Disordered	7m	30-180m	High	Infralittoral	350 tons Portuguese carrack (Camidge 2007, 2013c; Craddock and Hook 1995; Wessex Archaeology 2007)

	Easting	Northing	Site	Date	Seabed	Structural remains	Objects /Artefacts	Distribution	Average Depth	Distance to the coast	Energy	Biozone	Type
25	169392.1937	11383.35277	*Royal Anne*	1709-1721	Sand	No Structure	Some	Scattered Disordered	4m	180-200m	High	Infralittoral	Royal Navy Galley Frigate (Camidge and Johns 2014, 2016b; Camidge, Johns, and Panter 2011; Camidge, Johns, and Rees 2006, 2009; Wessex Archaeology 2005c)
26	243392.7204	47888.81694	*Coronation* Offshore	1685-1691	Sandy Gravel	No Structure	Few	Scattered Disordered	20m	900-950m	High	Shallow circalittoral	90-gun Second-rate (Berry and Camidge 2012; Holt 1997; MAST 2017; Wessex Archaeology 2004a)
27	243900.473	48597.04025	*Coronation* Inshore	1685-1691	Sandy Gravel	No Structure	Some	Scattered Disordered	7m	180-200m	High	Infralittoral	90-gun Second-rate (Berry and Camidge 2012; Holt 1997; MAST 2017; Wessex Archaeology 2004a)

	Easting	Northing	Site	Date	Seabed	Structural remains	Objects /Artefacts	Distribution	Average Depth	Distance to the coast	Energy	Biozone	Type
28	260933.4061	47102.77405	Erme Estuary	Medieval-early 19th C.	Gravelly Sand	No Structure	Few	Scattered Disordered	3m	100-150m	High	Infralittoral	Cannon site/anchors and loos shot (Oldham, Palmer, and Tyson 1993)
29	173700.0861	53200.90278	*Hanover*	18th c. 1757-1763	Gravelly Sand	Elements	Some	Scattered Ordered	4m	50-200m	High	Infralittoral	Brigantine (Dresch and Evans 2017; Parham, Underwood, and Brown 2013)
30	648566.9605	267863.1955	Dunwich *Bank*	16th C.	Sand	Elements	Few	Scattered Disordered	10m	850-900m	High	Shallow circalittoral	Unidentified Guns, timbers, (Wessex Archaeology 2006a)
31	275531.0535	36146.86661	Salcombe Cannon Site	17th C.	Gravelly Sand	No Structure	Few	Scattered Disordered	10m	350-400m	High	Infralittoral	Unidentified (Pink 2016:62; Tyson and Palmer 2013; Wessex Archaeology 2006d)

	Easting	Northing	Site	Date	Seabed	Structural remains	Objects /Artefacts	Distribution	Average Depth	Distance to the coast	Energy	Biozone	Type
32	463270.8855	96418.34225	*Mary Rose*	1509-1545	Sandy Mud	Extensive	Many	Coherent	10m	1.8-2km	Low	Shallow circalittoral	Tudor (Bridge 2011; Dobbs 1995; Marsden 2003; Mary Rose Museum 2018; Mckee 1982; Quinn, Bull, Dix, et al. 1997; Quinn, Bull, and Dix 1997)
33	164593.5405	23336.0992	Loe Bar Wreck	1671-1684	Sand	No Structure	Some	Scattered Disordered	11m	120-200m	High	Infralittoral	*The President.* 500 tone *English East Indiamen* (Wessex Archaeology 2005b)
34	452990.0247	529571.6249	Seaton Carew	18th C.	Sand	Extensive	Some	Coherent	0m	0	High	Sublittoral fringe	18th c. Collier brig (Ch2m 2007:7–4, 7–10)
35	88363.29129	11621.46993	*HMS Colossus*	1787-1798	Gravelly Sand	Elements	Some	Coherent	13m	200-400m	High	Infralittoral	74-gun Third-rate ship (Camidge 2017; Camidge et al. 2015; CISMAS 2006; Morris 1979)

	Easting	Northing	Site	Date	Seabed	Structural remains	Objects /Artefacts	Distribution	Average Depth	Distance to the coast	Energy	Biozone	Type
36	625265.0338	186163.4586	South Edinburgh Channel	1787	Gravelly Mud	Elements	Some	Coherent	11m	16-17km	Moderate	Shallow circalittoral	Swedish cargo vessel (Muckelroy 1978:182; Parham, Rundell, and van der Merwe 2013; Wessex Archaeology 2004b)
37	515931.2396	478781.2237	Filey Bay Wreck	1779	Gravelly Sand	Elements	Few	Scattered Disordered	25m	3.5-4km	Moderate	Shallow circalittoral	*Bonhome Richard* (OESEA3 2014:715; Wessex Archaeology 2003a)
38	577685.2958	91304.68047	*Holland No.5*	1902-1912	Gravelly Sand	Extensive	Some	Coherent	30m	16-17km	Moderate	Shallow circalittoral	Submarine Holland class (Beattie-Edwards 2014; NAS & 3Deep n.d.; Wessex Archaeology 2009)
39	405378.2605	84964.68574	Swash Channel Wreck	1630-1699	Gravel	Elements	Many	Scattered Disordered	8m	1.3-2km	Moderate	Infralittoral	Dutch merchantman (Nayling 2010; Palma and Parham 2006, 2007; Parham 2010, 2011)

	Easting	Northing	Site	Date	Seabed	Structural remains	Objects /Artefacts	Distribution	Average Depth	Distance to the coast	Energy	Biozone	Type
40	345123.597	89670.06664	West Bay	1627-1750	Gravelly Sand	No Structure	Few	Scattered Disordered	12m	970m-1km	High	Infralittoral	Pig iron and scrap guns (Johns et al. 2015:20; Wessex Archaeology 2018c)
41	569959.919	103145.74	Norman's Bay Wreck	1672-1690 c.	Gravelly Sand	Elements	Some	Scattered Disordered	6m	2.8-3km	High	Shallow circalittoral	Dutch Third-rate man of war 66-guns *Wapen van Utrecht* possibly (Beattie-Edwards 2017; Beattie-Edwards, Le Fevre, and Fox 2017)
42	649487.46	158840.402	*Rooswijk*	1738-1740	Gravelly Sand	Elements	Some	Scattered Ordered*	24m	12.7-13km	Moderate	Shallow circalittoral	Dutch East Indiamen VOC (MSDS Marine Ltd 2018; PAS 2017:10,20; WA 2007)
43	93525.0043	13262.69513	*Wheel Wreck*	19th c.	Gravelly Sand	No Structure	Some	Scattered Disordered	16m	200-500m	Moderate	Infralittoral	Mining equipment (Camidge and Johns 2017:23–24; Historic Environment 2017:11)

	Easting	Northing	Site	Date	Seabed	Structural remains	Objects /Artefacts	Distribution	Average Depth	Distance to the coast	Energy	Biozone	Type
44	428940.0979	84810.42904	The Needles Site	Mid-18th c. and early 19th c.	Gravelly sand	Elements	Some	Scattered Disordered	6m	200-300m	High	Infralittoral	*HMS Assurance* 44- gun (1753), *HMS Pomone* 38-gun (1805-1811)[1] and *Anglo Saxon* (1879). (HWTMA 2010; Satchell and Whitewright 2014; Tomalin, Simpson, and Bingeman 2000)
45	590016.1849	180959.077	*London*	1656-1665	Mud	Extensive	Many	Coherent	24m	3.5-3.9	Moderate	Shallow circalittoral	64-gun, second-rate ship (Artas Media 2018; PAS 2018)
46	639791.23	153779.32	GAD8	1650-1750	Slightly Gravelly Sand	Elements	Few	Scattered Ordered	15m	2.1-2.2km	Moderate	Shallow circalittoral	*Unidentified* wooden vessel (PAS 2017:15, 23; Wessex Archaeology 2011b)

[1] The majority of the *HMS Pomone* is found at the Alum Bay Wreck 1. The environment could have dragged the scattered elements from Alum Bay towards the Needles (Ortiz-Vázquez 2015; Satchell and Whitewright 2014; Whitwright and Satchell 2014).

	Easting	Northing	Site	Date	Seabed	Structural remains	Objects /Artefacts	Distribution	Average Depth	Distance to the coast	Energy	Biozone	Type
47	445516.725	94486.005	Thorness Bay Wreck	19th c.	Gravelly Sand	Elements	Few	Scattered Ordered	24m	540-700m	Moderate	Shallow circalittoral	*Unidentified* wooden vessel (Wessex Archaeology 2011a)
48	83305.091	5093.966	*Association*	1693-1707	Gravelly Sand	Elements	Some	Scattered Ordered	25m	300-500m	High	Infralittoral	90-gun Second-rate (CISMAS 2018; McBride and Larn 1999; Morris 1969; Owen 1991:330)
49	386728.047	69344.515	*HM Submarine A3*	1903-1912	Muddy Sandy Gravel	Extensive	Few	Coherent	38m	9.8-10	Moderate	Shallow circalittoral	British Submarine (McCartney 2002:77)
50	628901.38	119985.673	*SM U-8*	1911-1915	Gravelly Sand	Extensive	Some	Coherent	33m	16-20km	Moderate	Deep circalittoral	Submarine of the German Imperial Navy (Cotswold Archaeology Marine 2014; MSDS Marine Ltd & Artas Media 2018; Wessex Archaeology 2015)
51	395893.119	71473.857	*HMT Arfon*	1908-1917	Muddy Sandy Gravel	Extensive	Few	Coherent	35m	3.7-4km	Moderate	Deep circalittoral	Trawler (MAT & Artas Media 2018; MAT 2018)

	Easting	Northing	Site	Date	Seabed	Structural remains	Objects /Artefacts	Distribution	Average Depth	Distance to the coast	Energy	Biozone	Type
52	362278	79359	Chesil Beach Cannon Site	1650-1725	Sandy Gravel	No Structure	Few	Scattered Disordered	15m	60-200m	High	Shallow circalittoral	*Unidentified wreck*. (Wessex Archaeology 2018a, 2018b)
53	486245.274	515408.61	*SM UC-70*	1916-1918	Sand	Extensive	Few	Coherent	25m	9.7-11km	Moderate	Shallow circalittoral	German Submarine (Wessex Archaeology 2017)

Table 1. The table shows all of the Protected Wreck sites in England with an Environmental, according to the categories defines by the author of this thesis.

1.1.1 Protected Wreck at Risk

Protected Wreck site risk assessment based on HE guidelines (HE 2017:14, 15)

Figure 1. HE Risk Assessment decision-tree (HE 2017:14)

Wreck/Site Name	

NRHE / UKHO No.	HE Region	Restricted Area	Principal Land Use

Latitude (WGS84)	
Longitude	

Class Listing	Period	Status
Licensee	Nominated Archaeologist	Principal Ownership Category

Seabed Owner	Navigational Administrative Responsibility

Environmental Designations

Seabed Sediment	Energy

Survival

Overall Condition	Condition Trend	Principal Vulnerability

Amenity Value: visibility

Amenity Value: physical accessibility	Amenity Value: intellectual accessibility

Management Action														
Management Prescription	A	B	C	D	E	F	G	H	I	J	K	L	M	N

Notes:

Risk is assessed as: **High / Medium / Low**

Data Source		Date & Initials	
Date of previous assessment:		Has an ecological survey been undertaken? Y / N	

Figure 2. HE Risk Assessment Template Sheet (HE 2017:15)

1.2 List of Protected Wrecks of Wales and Northern Ireland and Protected Historic Marine Areas of Scotland.

The list contains

- Protected Wreck Number.
- Positioning (easting and northing) in WGS84 (Geography & Technology 2018; Historic Environment Scotland 2016; Open Data NI 2018).
- Wrecks name
- Date or launching and wrecking or approximate date for unidentified vessels.
- Seabed Substratum according to Folk's (Long 2006) classification.
- Structural remains (extensive, elements or no Structure).
- Objects/artefacts (many, some, few).
- Distribution (coherent, scattered ordered or scattered disordered).
- The average depth of site in metres.
- Distance to the coast in kilometres.
- Energy (high, medium or low) according to EMODnet (EMODnet 2018).

Number	Easting	Northing	Site	Date	Seabed	Structural remains	Objects /Artefacts	Distribution	Average Depth	Distance to the coast	Energy
DW1	-4.12550	52.778833	Bronze Bell	1702c.	Sand	Elements	Some	Scattered Ordered	11m	400m	High
DW2	-4.19528	53.212778	Pwll Fanog	Post Medieval	Sand	Elements	Few	Scattered Ordered	11m	100-200m	Low
DW3	-4.61111	53.421111	Royal Yacht Mary	1660-1675	Sand	Elements	some	Scattered Disordered	10 m	100-200m	High
DW4	-5.67028	51.721667	The Smalls	19-20th c.	Sandy Gravel	No Structure	Few	Scattered Disordered	11m	100-200m	Moderate
DW5	-3.55300	53.396333	Resurgam	1879-1880	Sandy Gravel	Extensive	Few	Coherent	8m	7.9-8km	High
DW6	-4.18403	52.781417	Diamond	19th century	Gravel	Elements	Few	Scattered Ordered	8m	3.5km	High
PWA73	-6.50180	55.247500	Girona	27/10/1588	Sandy Gravel	No Structure	Few	Scattered Disordered	8m	80-100m	High
HMPA7	-5.656435	56.45734	Duart Point	17th century	Gravelly Muddy Sand	No Structure	Few	Scattered Disordered	8m	50-100m	Low
HMPA6	-5.700250	56.50300	Dartmouth	1665-1690	Gravelly Muddy Sand	No Structure	Some	Scattered Ordered	6m	50-100m	Low
HMPA5	-0.752017	60.41945	Out Skerries	1664	Gravelly Sand	Elements	Many	Scattered Ordered	17m	100-300m	High
HMPA5	-0.723133	60.42445	Out Skerries	1687	Gravelly Sand	Elements	Many	Scattered Disordered	25m	100-300m	Moderate
HMPA4	-3.224950	56.04007	Campania	1892-1918	Gravelly Muddy Sand	Extensive	Some	Scattered Ordered	12m	1.7-1.8km	Low
HMPA3	-5.108450	58.43648	Kinlochbervie	17th century	Gravelly Sand	No Structure	Few	Scattered Ordered	10m	50-100m	High
HMPA2	-6.073550	56.69147	Mingary	17th century	Gravelly Sand	Elements	Few	Scattered Ordered	10m	50-100m	Moderate
HMPA1	-5.197800	58.25058	Drumbeg	17-18th century	Gravelly Sand	Elements	Few	Scattered Ordered	9m	500m	Moderate
HMPA8	-4.786567	55.96793	Iona I	1855-1862	Sandy Mud	Extensive	Some	Coherent	27m	500-600m	Low

Table 2. List of the Protected Historical Marine Areas of Scotland and Protected wrecks of Wales, and Northern Ireland (Geography & Technology 2018; Historic Environment Scotland 2016; Open Data NI 2018).

1.3 List of MOD Designated Controlled Sites

The list of MOD designated controlled sites is plotted in WGS85 Decimal Degrees converted from Degrees Minutes Seconds, in the Military Wrecks Act 1986 Order 2017 (MOD 2017; The Crown Estate 1986).

ID	Num	Easting	Northing	Site	Area
1	(a)	0.650048	51.41678	HMS *Bulwark*	The area situated within 100 metres from the relevant point
2	(b)	-4.08342	57.6834	HMS *Natal*	The area situated within 100 metres from the relevant point
3	(c)	-4.28361	50.30014	HMS *A7*	The area situated within 200 metres from the relevant point
4	(d)	-5.00027	55.61687	HMS *Dasher*	The area situated within 200 metres from the relevant point
5	(e)	-2.98333	58.9169	HMS *Royal Oak*	The area situated within 200 metres from the relevant point
6	(f)	-3.10011	58.85011	HMS *Vanguard*	The area situated within 200 metres from the relevant point
7	(g)	-0.96676	50.48346	*UB-81*	The area situated within 250 metres from the relevant point
8	(h)	-4.6836	53.08347	HMS *H5*	The area situated within 300 metres from the relevant point
9	(i)	-3.38357	59.11685	HMS *Hampshire*	The area situated within 300 metres from the relevant point
10	(j)	-2.56682	49.8334	HMS *Affray*	The area situated within 400 metres from the relevant point
11	(k)	-3.06669	50.21672	HMS *Formidable*	The area situated within 400 metres from the relevant point
12	(l)	-2.46693	50.30013	HMS *Exmouth*	The area situated within 750 metres from the relevant point

Table 3. The table contained the Protected Military Remains in the UK.

1.4 Typology of Wrecks and Environment

1.4.1 Biozone

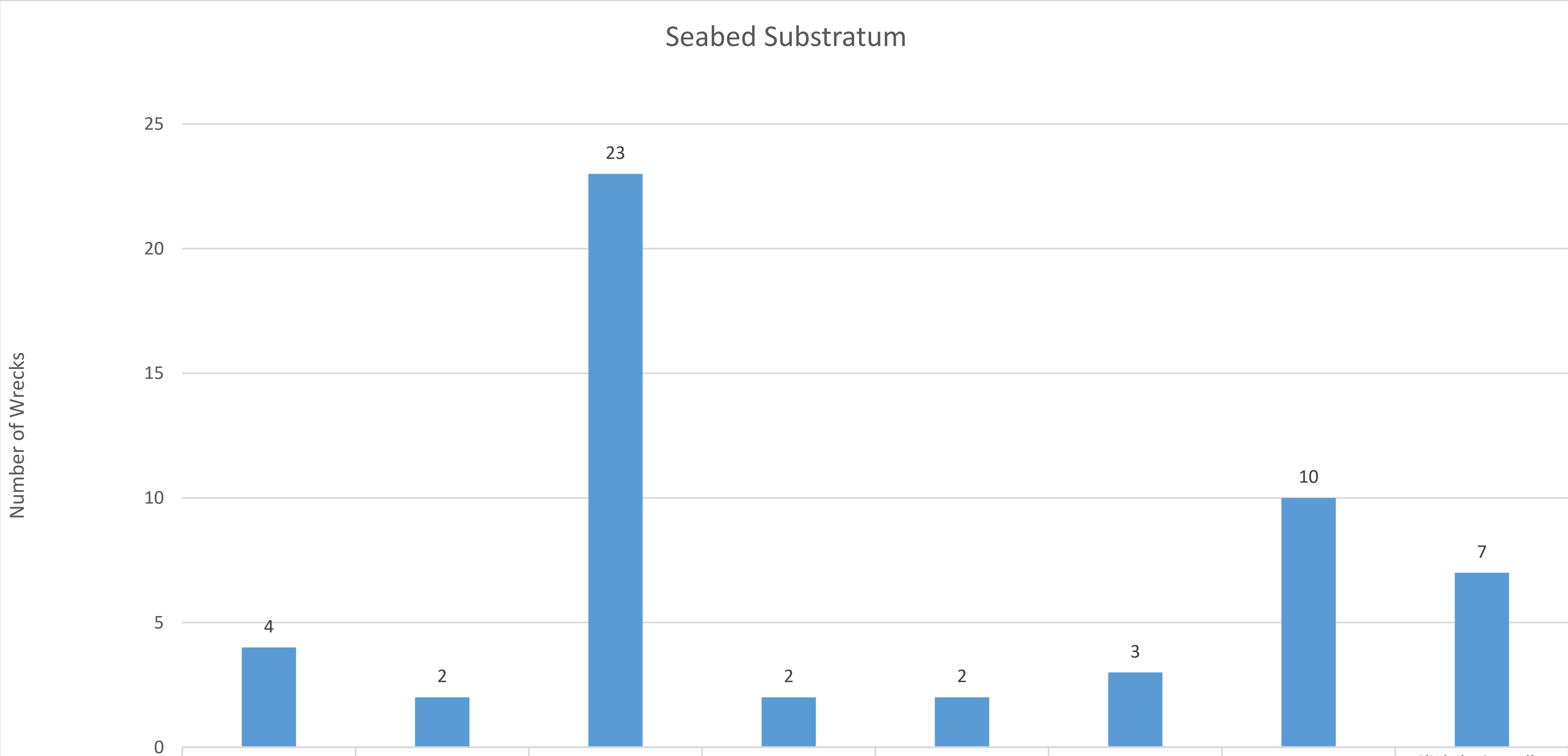
Biozone	Description
Infralittoral / Circalittoral	Rocky bottoms: The limit of domination of photophilic macroalgae caused primarily by decreasing light availability. It is also associated with increased stability in temperature, wave action, and salinity. Soft bottoms: A less distinct boundary but generally associated with the same variables described for rocky bottoms. See Connor et al. (2004)
Upper circalittoral / Lower circalittoral / Offshore Circalittoral	Rocky bottoms: The limit of all algae on rock caused primarily by decreasing light availability. It is also associated with further increasing stability in temperature, wave action, and salinity. Soft bottoms: The limit of disturbance-tolerant species caused primarily by increasing stability in wave action and temperature. It is also associated with further increasing stability in salinity and decreasing light availability. See Connor et al. (2004)
Circalittoral /Bathyal Changes	Changes in dominant fauna based on water mass properties: many variables including depth, salinity, temperature, dissolved oxygen and particulate organic carbon flux. Can be associated with the shelf edge delimited by the slope angle change of the continental platform. See Parry et al. (2015).
Upper bathyal/mid bathyal	Changes in dominant fauna based on water mass properties: many variables including depth, salinity, temperature, dissolved oxygen and particulate organic carbon flux See Parry et al. (2015).
Mid bathyal / lower bathyal	Changes in dominant fauna based on water mass properties: many variables including depth, salinity, temperature, dissolved oxygen and particulate organic carbon flux. See Parry et al. (2015).
Bathyal / Abyssal	Changes in dominant fauna based on water mass properties: many variables including depth, salinity, temperature, dissolved oxygen and particulate organic carbon flux. Can be associated with the lower limit of the continental slope delimited by the slope angle change of the continental platform. See Parry et al. (2015).
Upper abyssal/mid abyssal	Changes in dominant fauna based on water mass properties: many variables including depth, salinity, temperature, dissolved oxygen and particulate organic carbon flux. See Parry et al. (2015).

Mid abyssal / lower abyssal	Changes in dominant fauna based on water mass properties: many variables including depth, salinity, temperature, dissolved oxygen and particulate organic carbon flux See Parry et al. (2015).

Table 4. The table is based on the description provided by EMODnet (EMODnet; Parry et al.; Connor et al.)

1.4.2 Substratum

The graph represents the dominant substratum of the seabed where the position of wrecks was determined. The substratum is based on the marine sediments from EMODnet (2018), and BGS (2018), as well as reports and publications of each site specified on the Protected Wreck of England list.

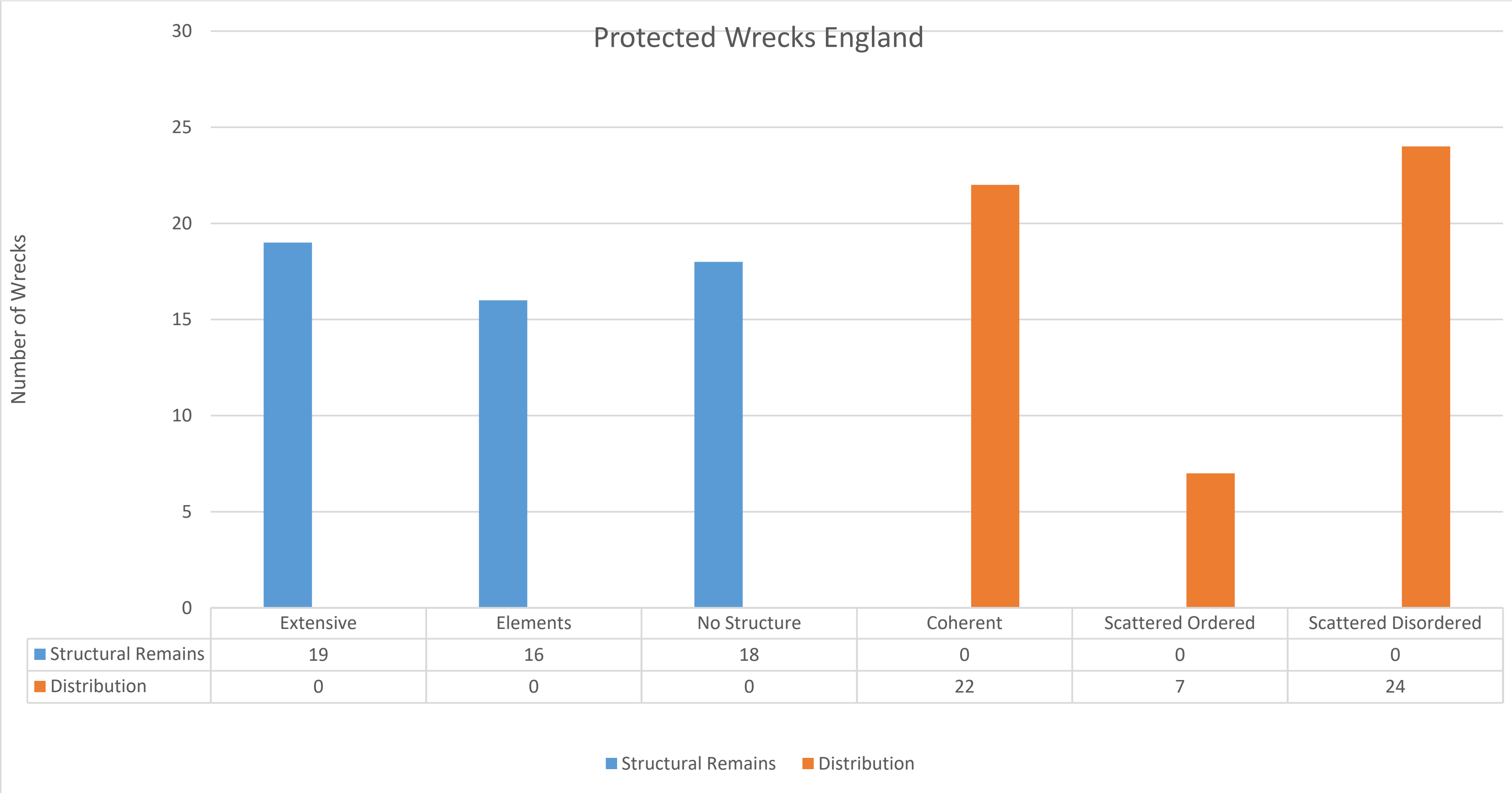


	Gravel	Gravelly Mud	Gravelly Sand	Mud	Muddy Sand	Muddy Sandy Gravel	Sand	Slightly Gravelly Sand
Frequencies	4	2	23	2	2	3	10	7

Figure 3. The graphic shows the number of Protected Wrecks in relation to seabed substratum.

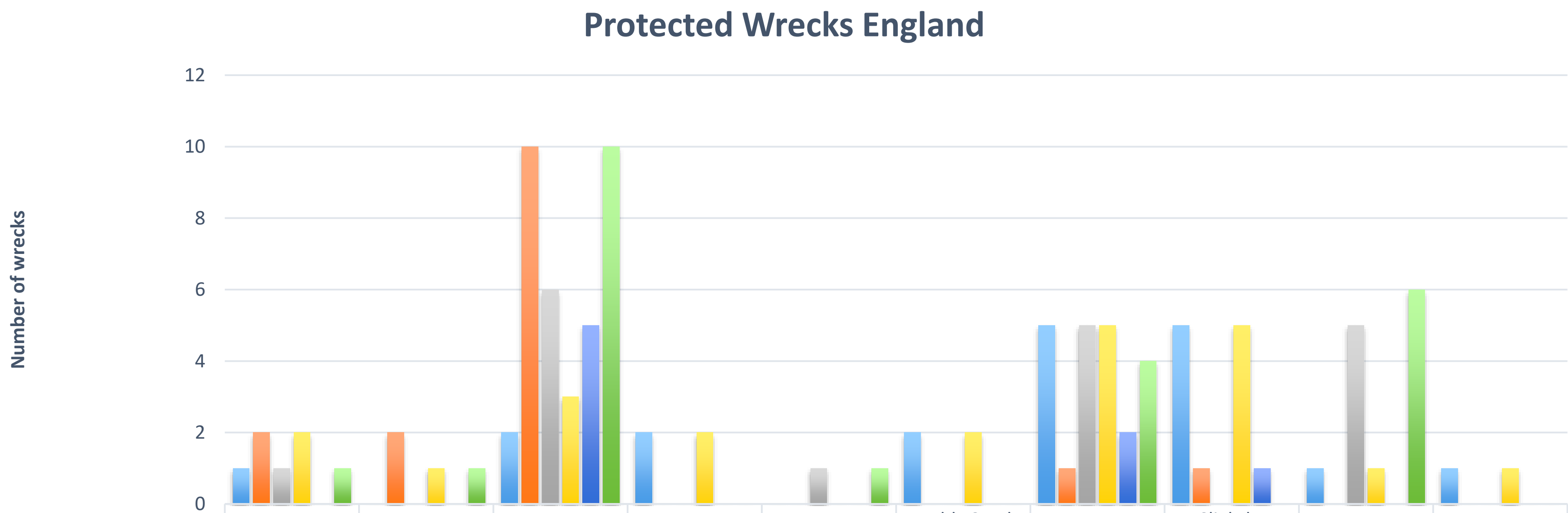
1.4.3 Structural Remains and Distribution (Biozone, Substratum, Depth, Distance to Coast and Energy)

This section represents the number of Protected Wrecks with the extent of their remains and their distribution in relation to the seabed substratum, depth, distance to the coast and the energy level of the environment.



	Extensive	Elements	No Structure	Coherent	Scattered Ordered	Scattered Disordered
Structural Remains	19	16	18	0	0	0
Distribution	0	0	0	22	7	24

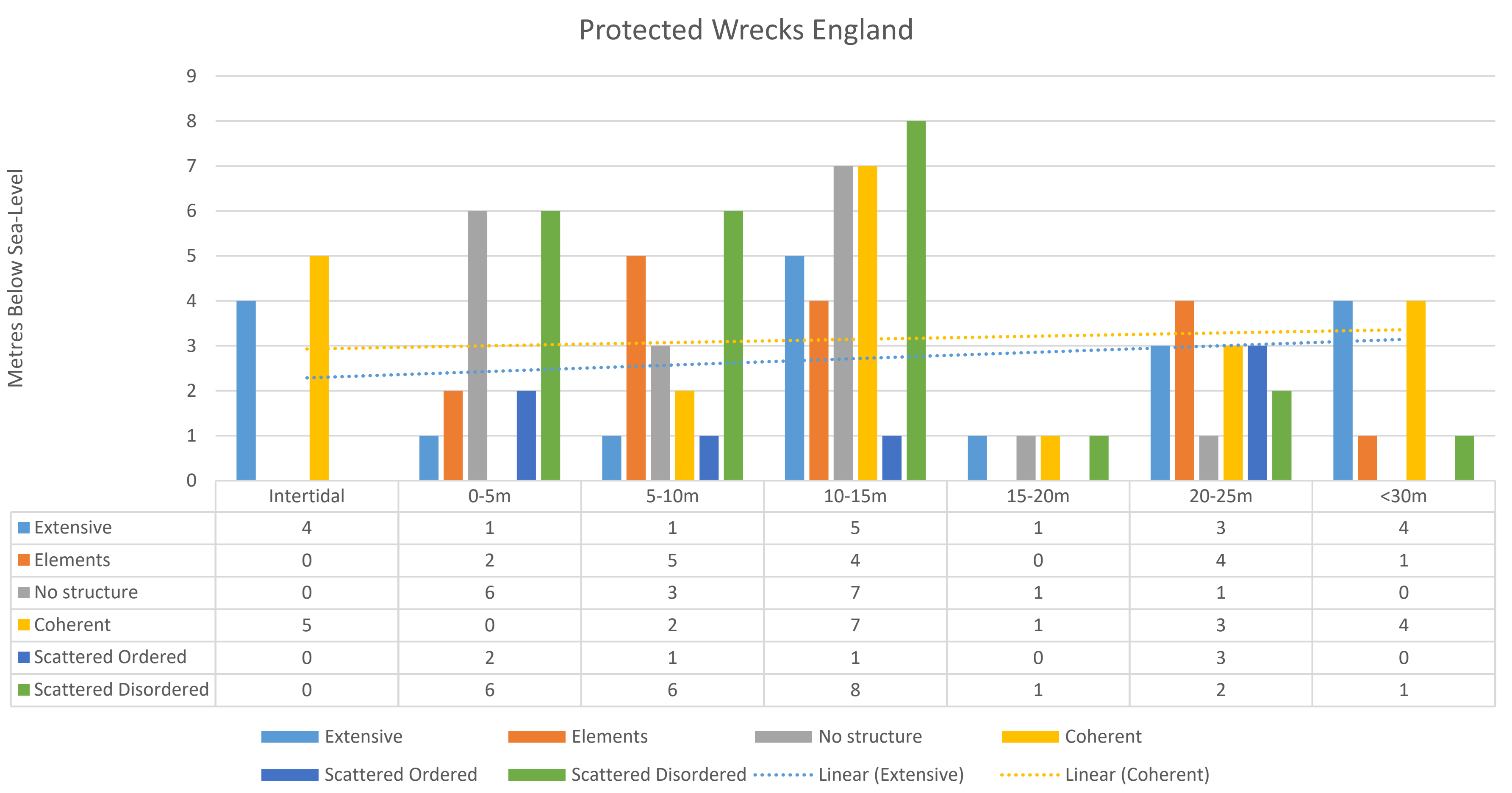
Figure 4. The graphic shows the number of Protected Wrecks in relation to structural integrity and distribution on the seabed.



	Gravel	Gravelly Mud	Gravelly Sand	Mud	Muddy Sand	Muddy Sandy Gravel	Sand	Slightly Gravelly Sand	Sandy Gravel	Sandy Mud
Extensive	1	0	2	2	0	2	5	5	1	1
Elements	2	2	10	0	0	0	1	1	0	0
No Structure	1	0	6	0	1	0	5	0	5	0
Coherent	2	1	3	2	0	2	5	5	1	1
Scaterred Ordered	0	0	5	0	0	0	2	1	0	0
Scattered Disordered	1	1	10	0	1	0	4	0	6	0

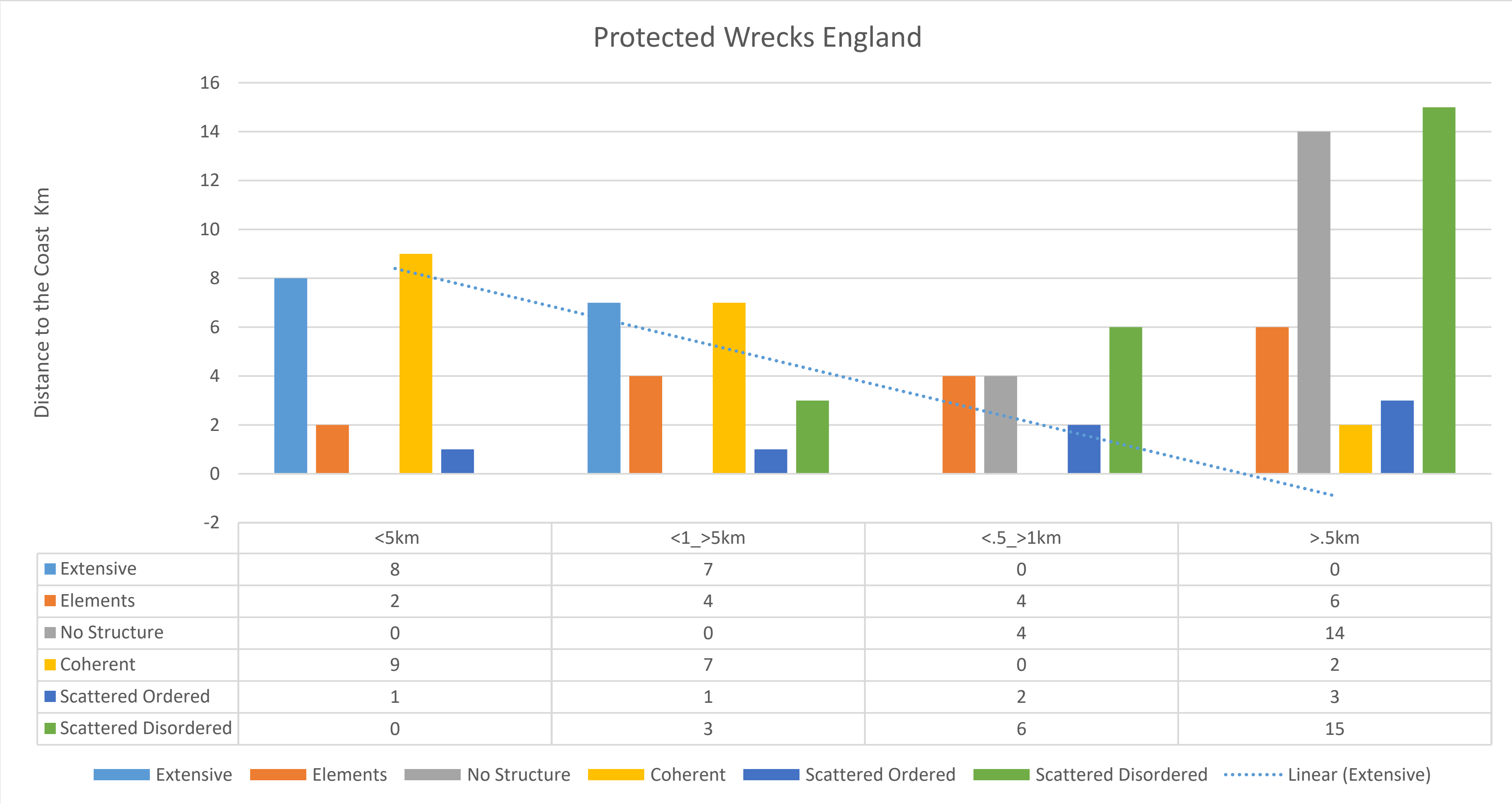
Extensive Elements No Structure Coherent Scaterred Ordered Scattered Disordered

Figure 5. The graphic shows the number of Protected Wrecks in co-relating the seabed substratum in relation to structural integrity and distribution on the seabed.



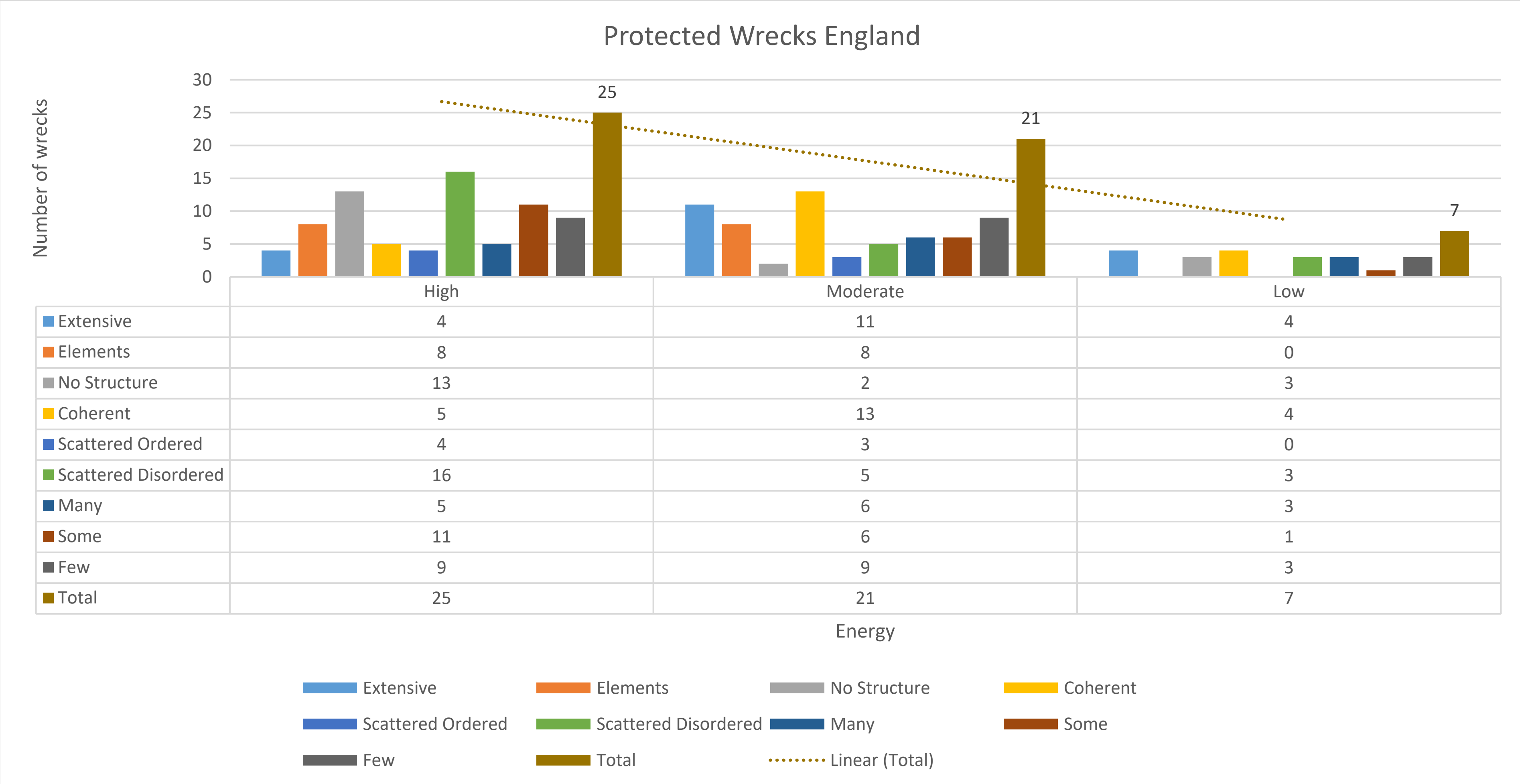
	Intertidal	0-5m	5-10m	10-15m	15-20m	20-25m	<30m
Extensive	4	1	1	5	1	3	4
Elements	0	2	5	4	0	4	1
No structure	0	6	3	7	1	1	0
Coherent	5	0	2	7	1	3	4
Scattered Ordered	0	2	1	1	0	3	0
Scattered Disordered	0	6	6	8	1	2	1

Figure 6. The graphic shows the number of Protected Wrecks, relating the Depth with the Structural Remains (Extensive, Elements and No Structure) and the Distribution (Coherent, Scattered Ordered and Scattered Disordered.



	<5km	<1_>5km	<.5_>1km	>.5km
Extensive	8	7	0	0
Elements	2	4	4	6
No Structure	0	0	4	14
Coherent	9	7	0	2
Scattered Ordered	1	1	2	3
Scattered Disordered	0	3	6	15

Figure 7. The graphic shows the number of Protected Wrecks, relating Distance to the coast with the structural (Extensive, Elements and No Structure) and the distribution on the seabed (Coherent, Scattered Ordered and Scattered Disordered).



	High	Moderate	Low
Extensive	4	11	4
Elements	8	8	0
No Structure	13	2	3
Coherent	5	13	4
Scattered Ordered	4	3	0
Scattered Disordered	16	5	3
Many	5	6	3
Some	11	6	1
Few	9	9	3
Total	25	21	7

Figure 8. The graphic shows the number of Protected Wrecks, relating the Energy-levels of the environments with the structural (Extensive, Elements and No Structure) and the distribution on the seabed (Coherent, Scattered Ordered and Scattered Disordered), and a number of artefacts on site (Few, Some and Many).

1.5 Marine Environments, Structural remains and Distribution of Wrecks around the UK

The following maps include positions, names and designated areas of protection for wrecks around the UK:

Environmental record

- Bathymetry (CCO 2018; EMODnet 2018; UKHO 2018).
- Energy (EMODnet 2018).
- Biozone (EMODnet 2018).
- Substratum (BGS 2018; EMODnet 2018).
- Coastlines and boundaries (Edina 2018; EEA 2018; National Geospatial-Intelligence Agency 2018).

- Protected wreck sites of
  - England (HE 2018a).
  - Scotland (Historic Environment Scotland 2016).
  - Wales (Geography & Technology 2018).
  - Northern Ireland (Open Data NI 2018).

- UKHO wrecks (Edina 2018; UKHO 2018)[2].
- WA wrecks[3] (Wessex Archaeology 2013).

Shipwreck classification by Structural remains and distribution was made reviewing grey literature, reports, and publication of each site that are referred on the PW list of this appendix.

[2] Courtesy of Bournemouth University (BU)
[3] Modified list from original WA (2013).

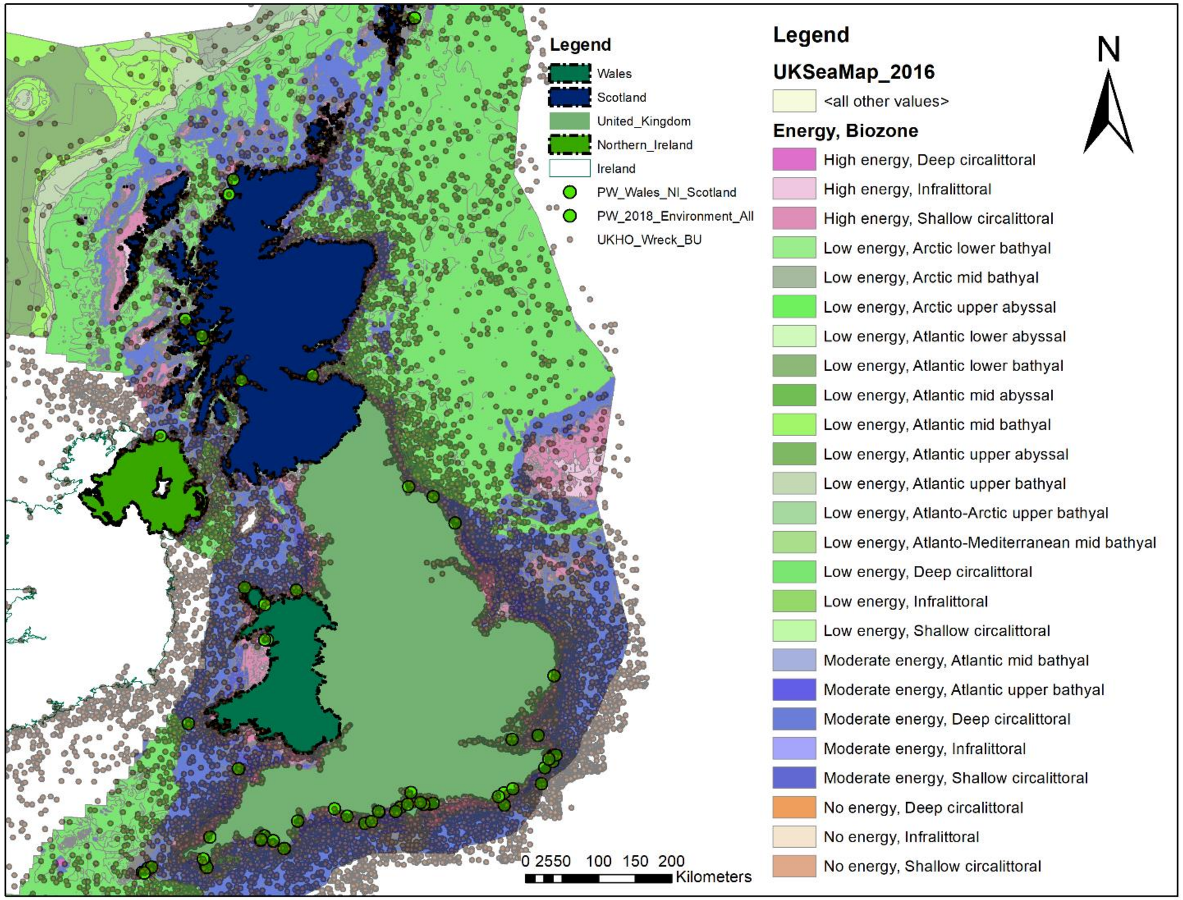


Figure 9. Energy levels of environments around the UK (High, Moderate and Low) (EMODnet 2018)**. Wrecks plotted from the UKHO and Protected wreck sites from HE, HES, CADW** (Geography & Technology 2018; HE 2018a; Historic Environment Scotland 2016)**. The author of this thesis created the map with ArcMap 10.5 ®.**

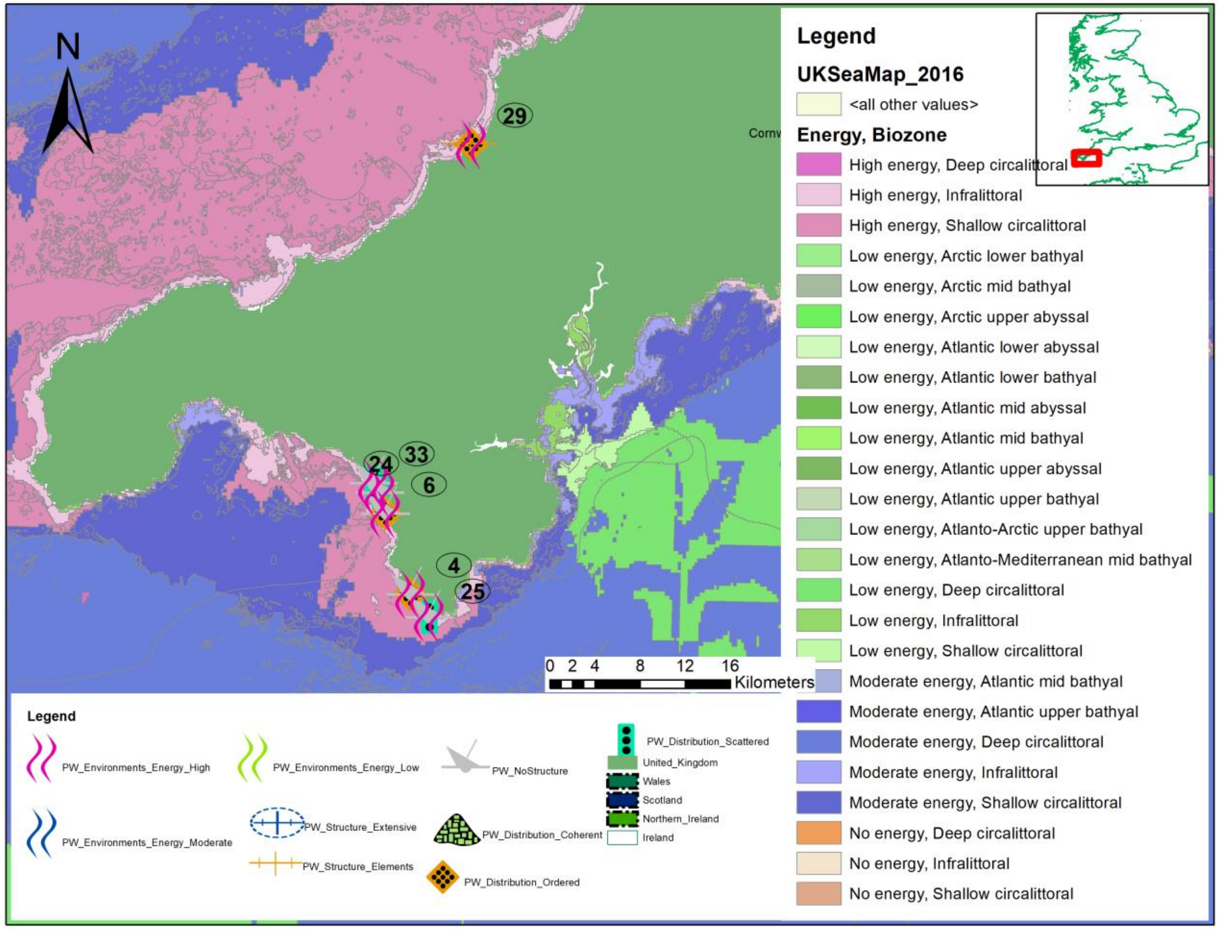


Figure 10 Cornwall, England. Energy levels of environments around the UK (High, Moderate and Low) (EMODnet 2018)**. Wrecks plotted from HE** (HE 2018a)**. The author of this thesis created the map with ArcMap 10.5 ®. The site classification was created based on chapter IV.**

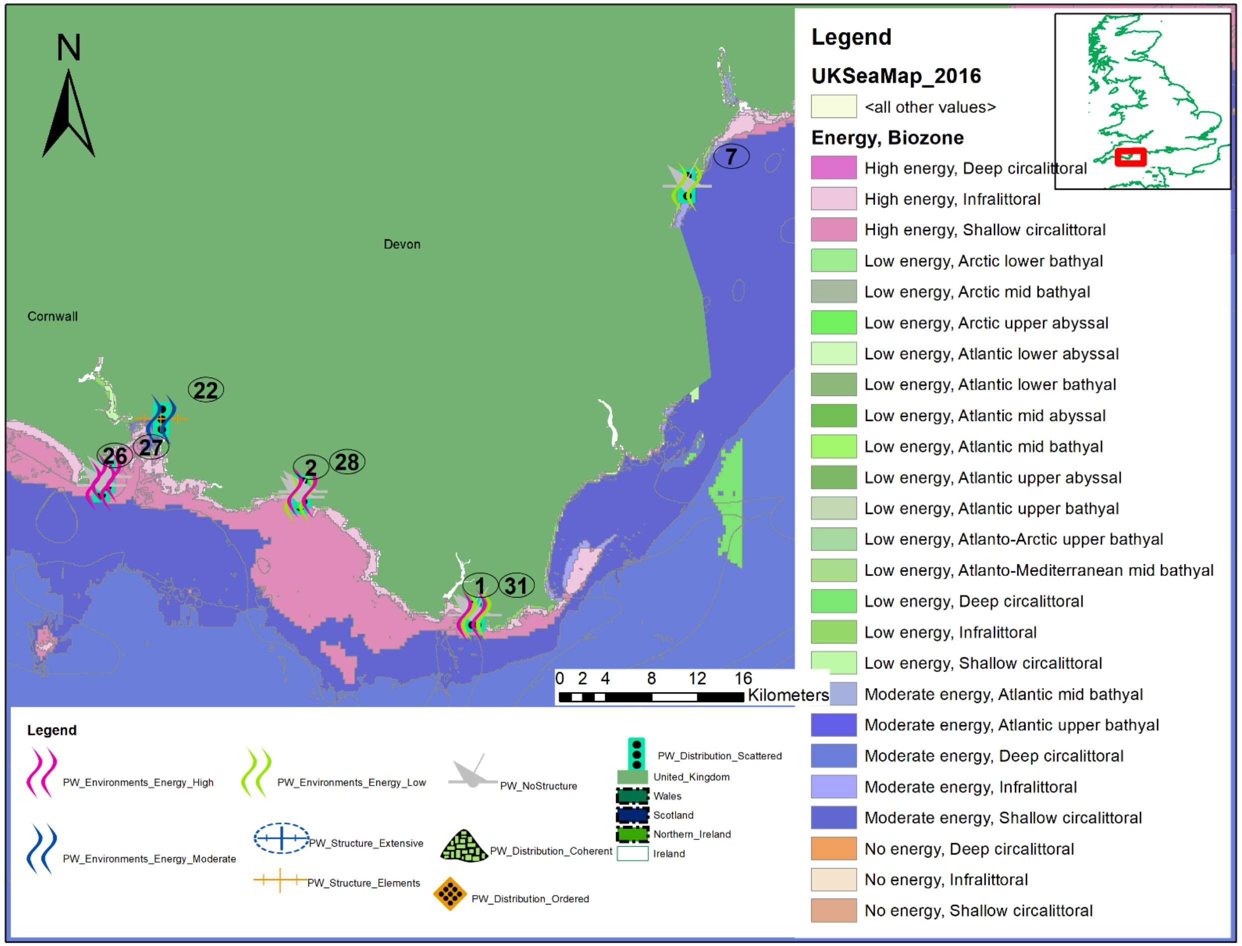


Figure 11. Devon, England. Energy levels of environments around the UK (High, Moderate and Low) (EMODnet 2018)**. Wrecks plotted from HE** (HE 2018a)**. The author of this thesis created the map with ArcMap 10.5 ®. The site classification was created based on chapter IV.**

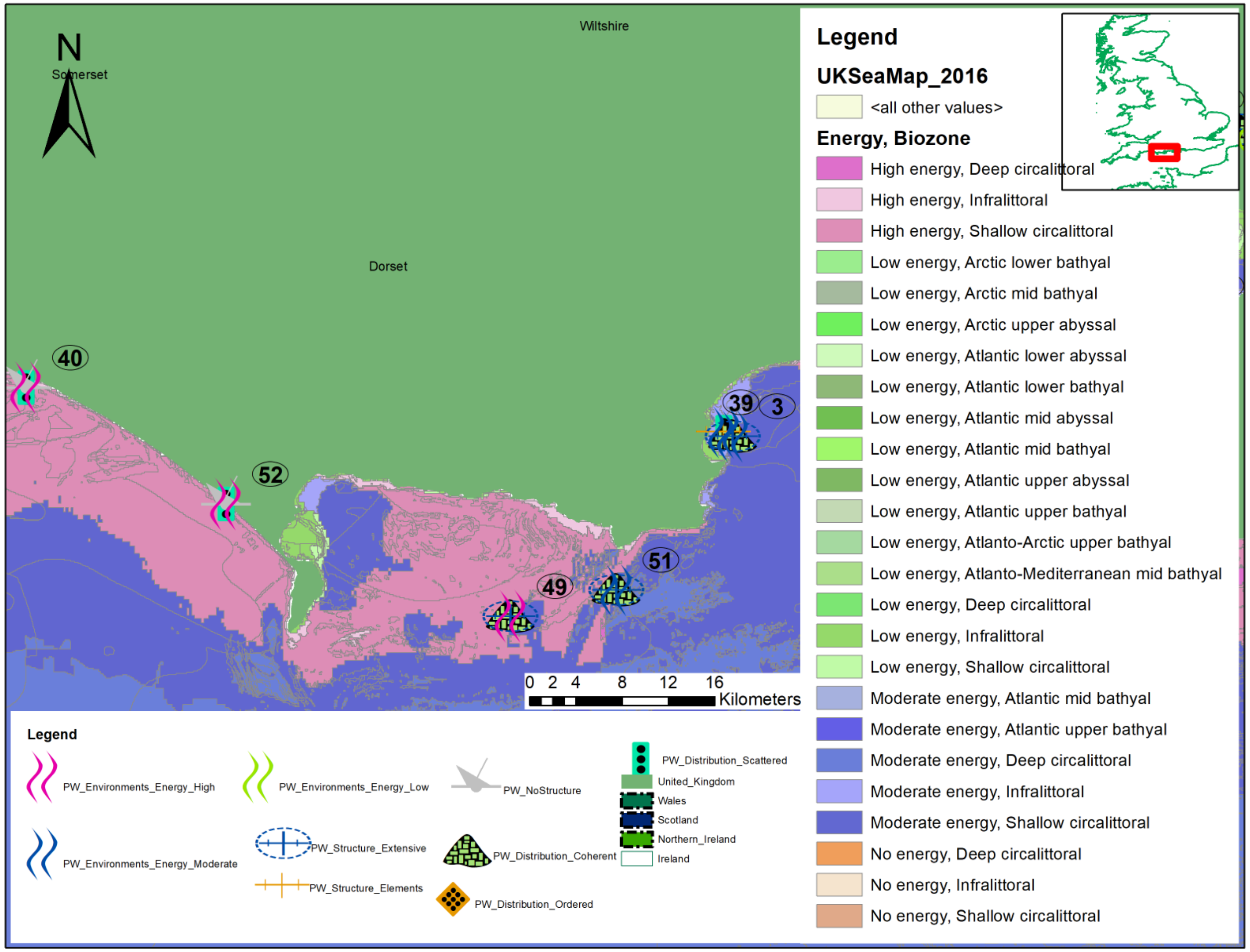


Figure 12. Dorset, England. Energy levels of environments around the UK (High, Moderate and Low) (EMODnet 2018)**. Wrecks plotted from HE** (HE 2018a)**. The author of this thesis created the map with ArcMap 10.5 ®. The site classification was created based on chapter IV.**

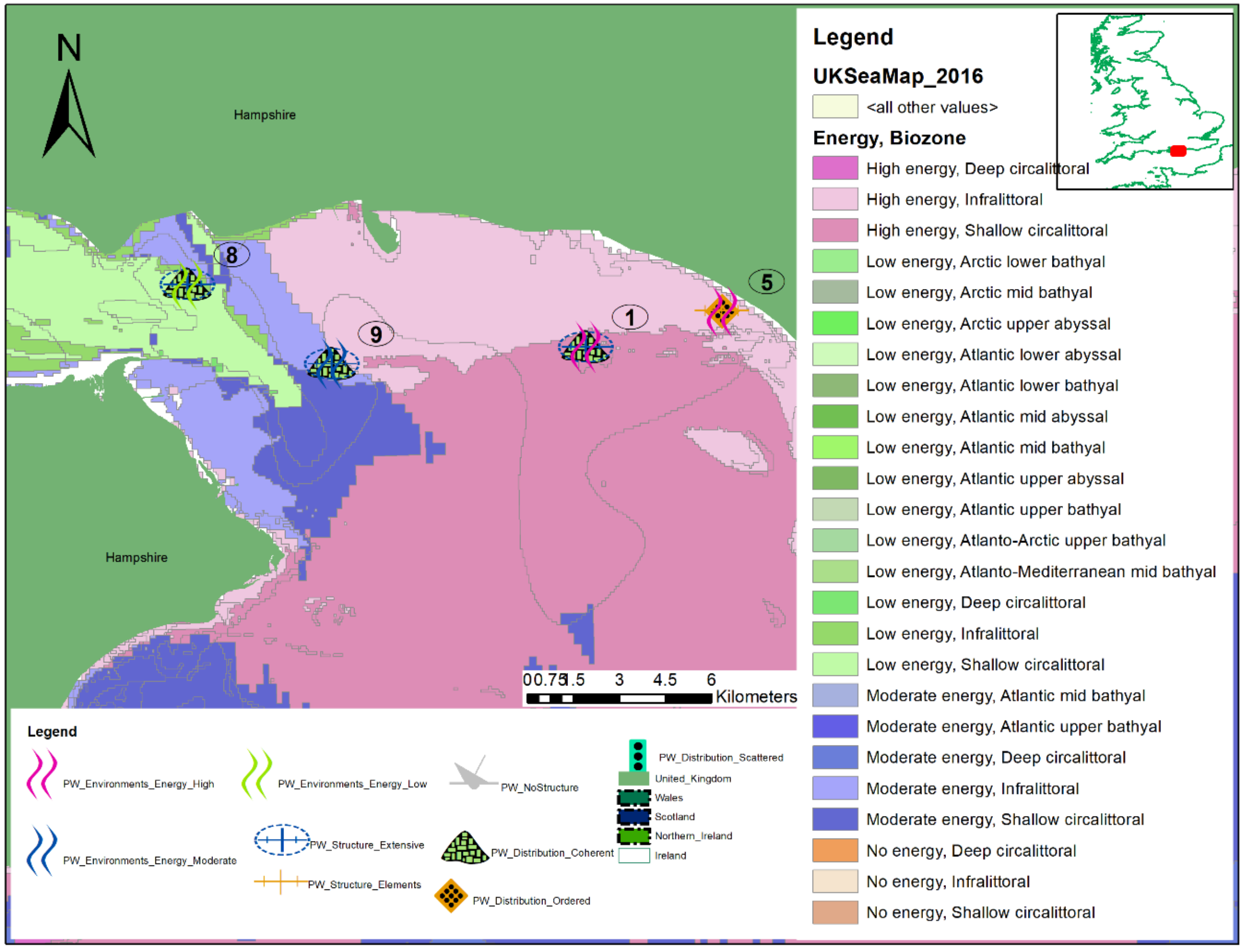


Figure 13. East Solent, England. Energy levels of environments around the UK (High, Moderate and Low) (EMODnet 2018)**. Wrecks plotted from HE** (HE 2018a)**. The author of this thesis created the map with ArcMap 10.5 ®. The site classification was created based on chapter IV.**

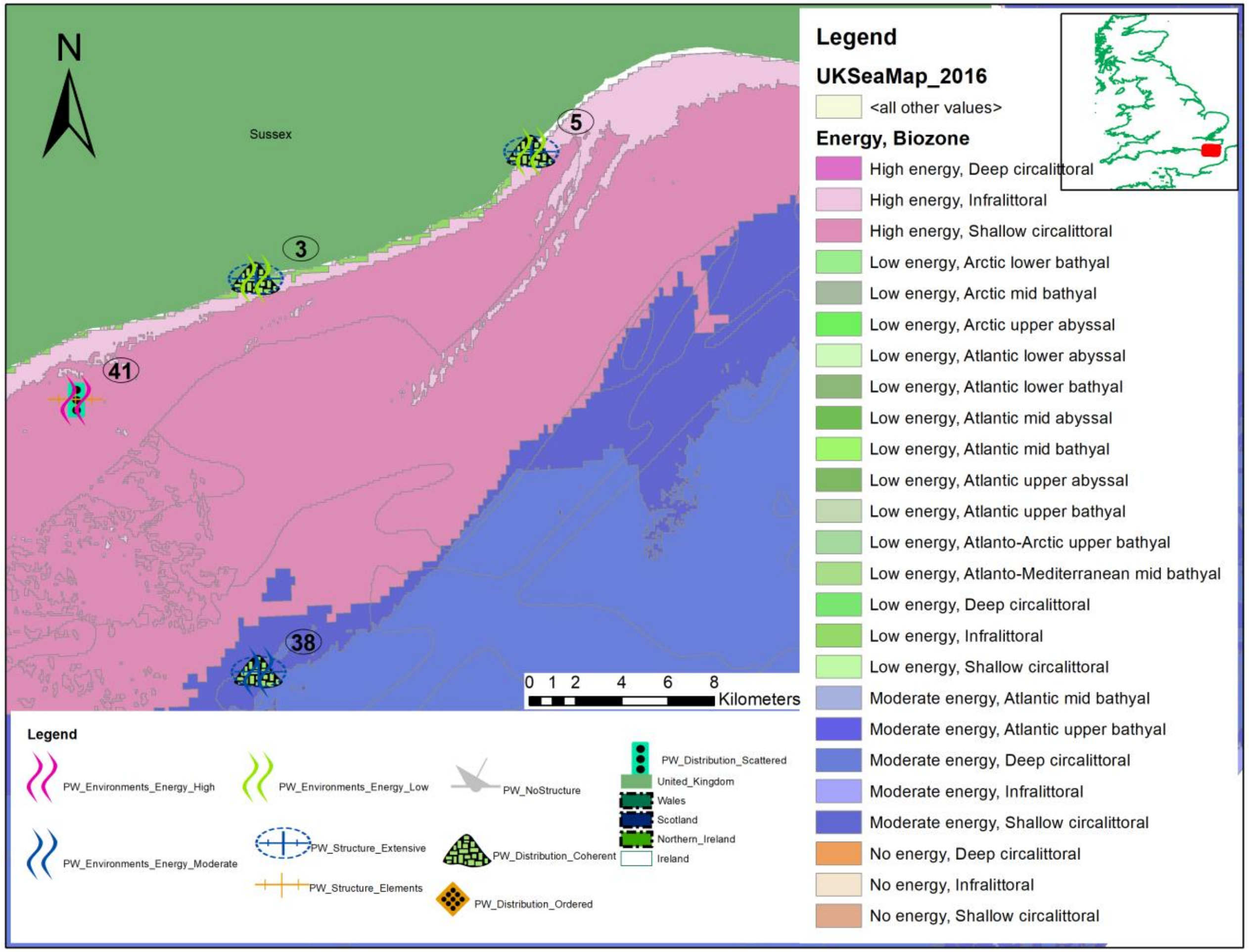


Figure 14. East Sussex, England. Energy levels of environments around the UK (High, Moderate and Low) (EMODnet 2018)**. Wrecks plotted from HE** (HE 2018a)**. The author of this thesis created the map with ArcMap 10.5 ®. The site classification was created based on chapter IV.**

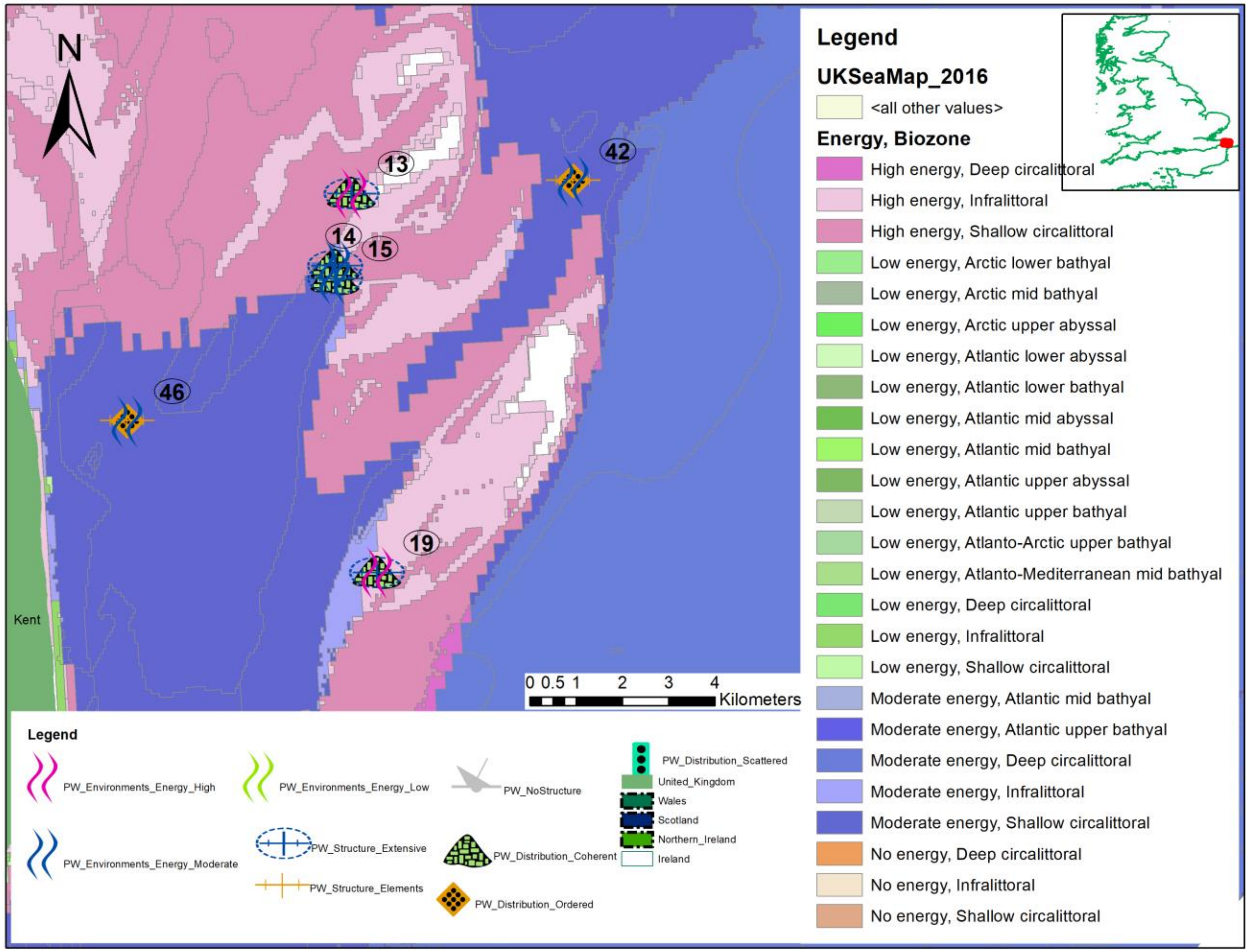


Figure 15. Goodwin Sands, England. Energy levels of environments around the UK (High, Moderate and Low) (EMODnet 2018)**. Wrecks plotted from HE** (HE 2018a)**. The author of this thesis created the map with ArcMap 10.5 ®. The site classification was created based on chapter IV.**

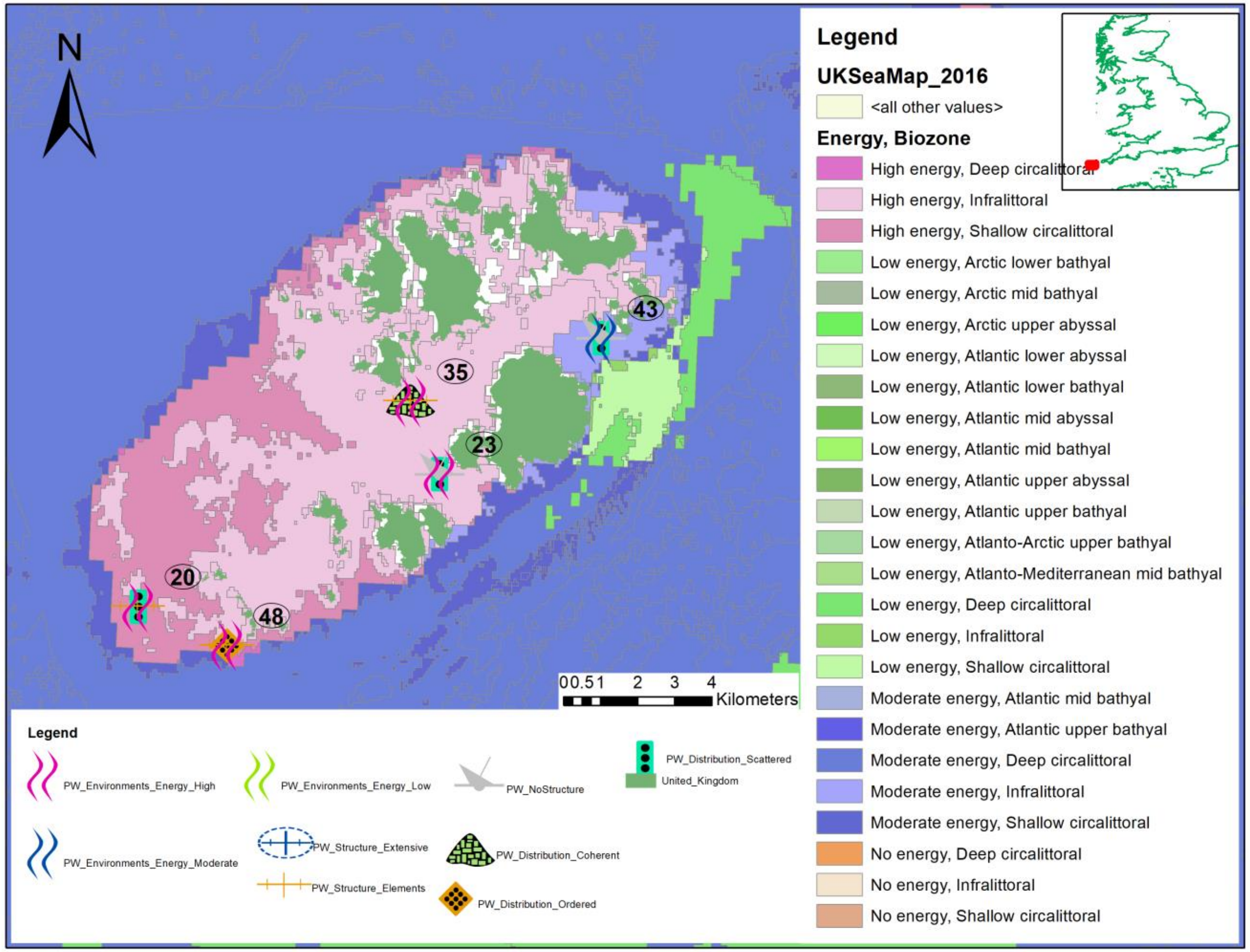


Figure 16. Isles of Scilly, England. Energy levels of environments around the UK (High, Moderate and Low) (EMODnet 2018)**. Wrecks plotted from HE** (HE 2018a)**. The author of this thesis created the map with ArcMap 10.5 ®. The site classification was created based on chapter IV.**

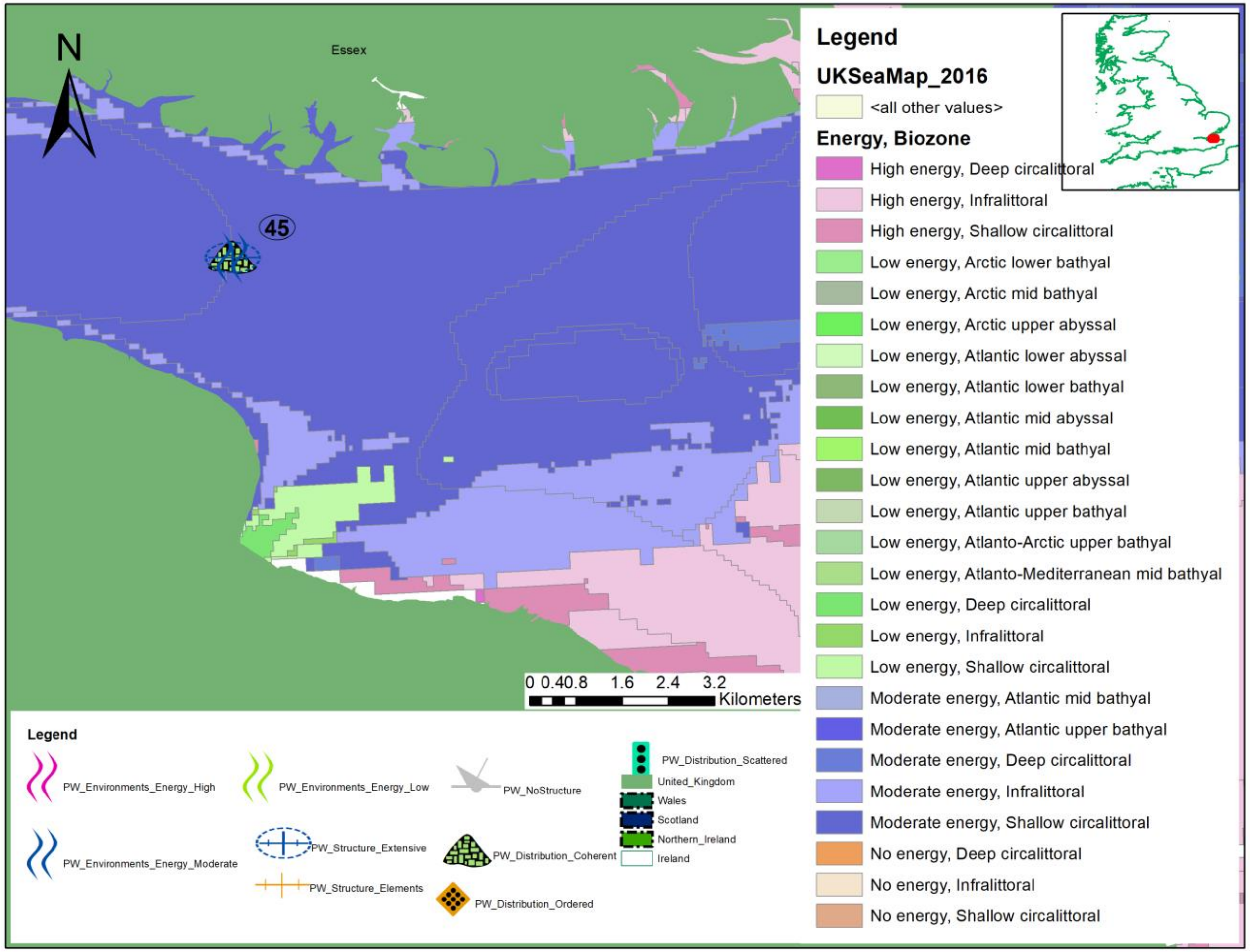


Figure 17. Thames Estuary, England. Energy levels of environments around the UK (High, Moderate and Low) (EMODnet 2018)**. Wrecks plotted from HE** (HE 2018a)**. The author of this thesis created the map with ArcMap 10.5 ®. The site classification was created based on chapter IV.**

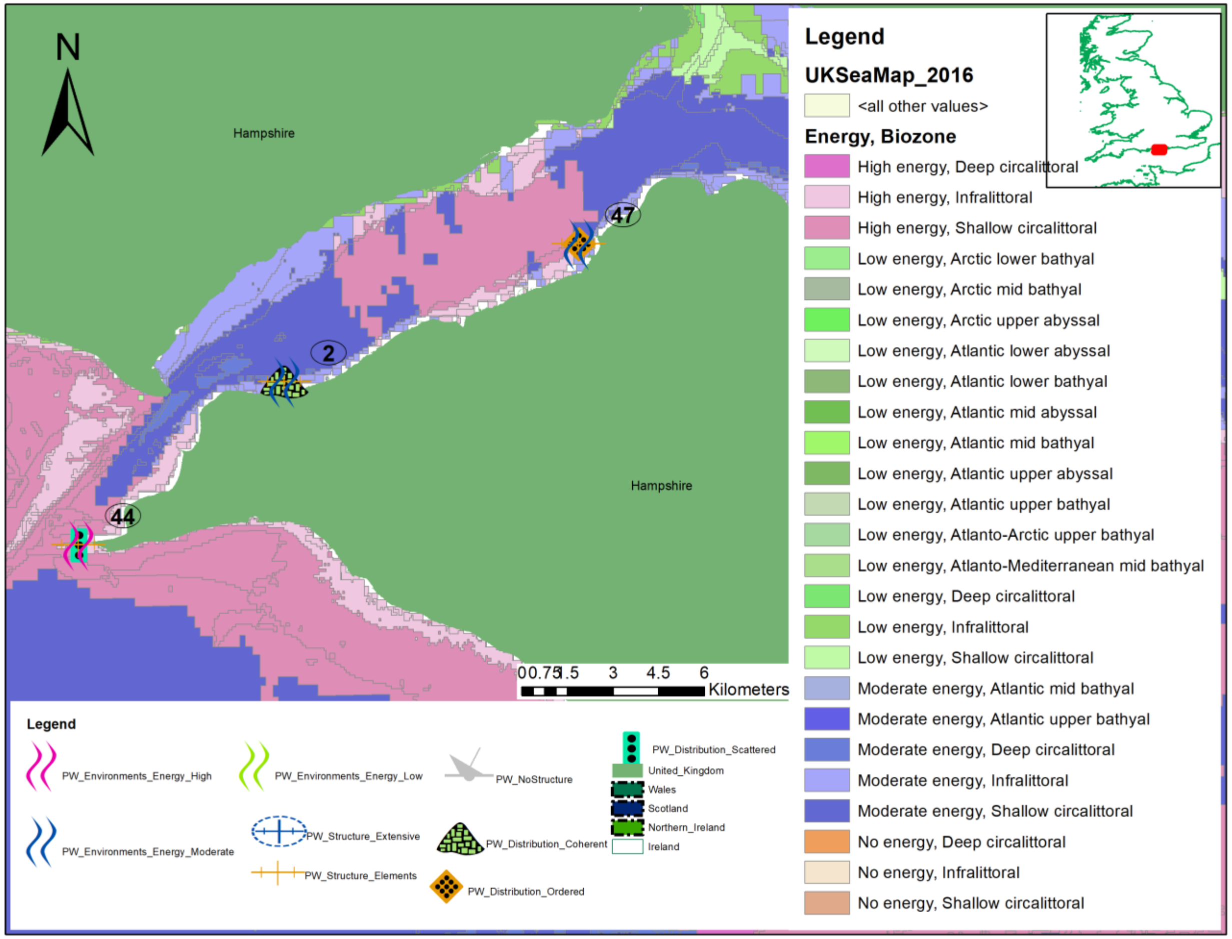


Figure 18. West Solent, England. Energy levels of environments around the UK (High, Moderate and Low) (EMODnet 2018)**. Wrecks plotted from HE** (HE 2018a)**. The author of this thesis created the map with ArcMap 10.5 ®. The site classification was created based on chapter IV.**

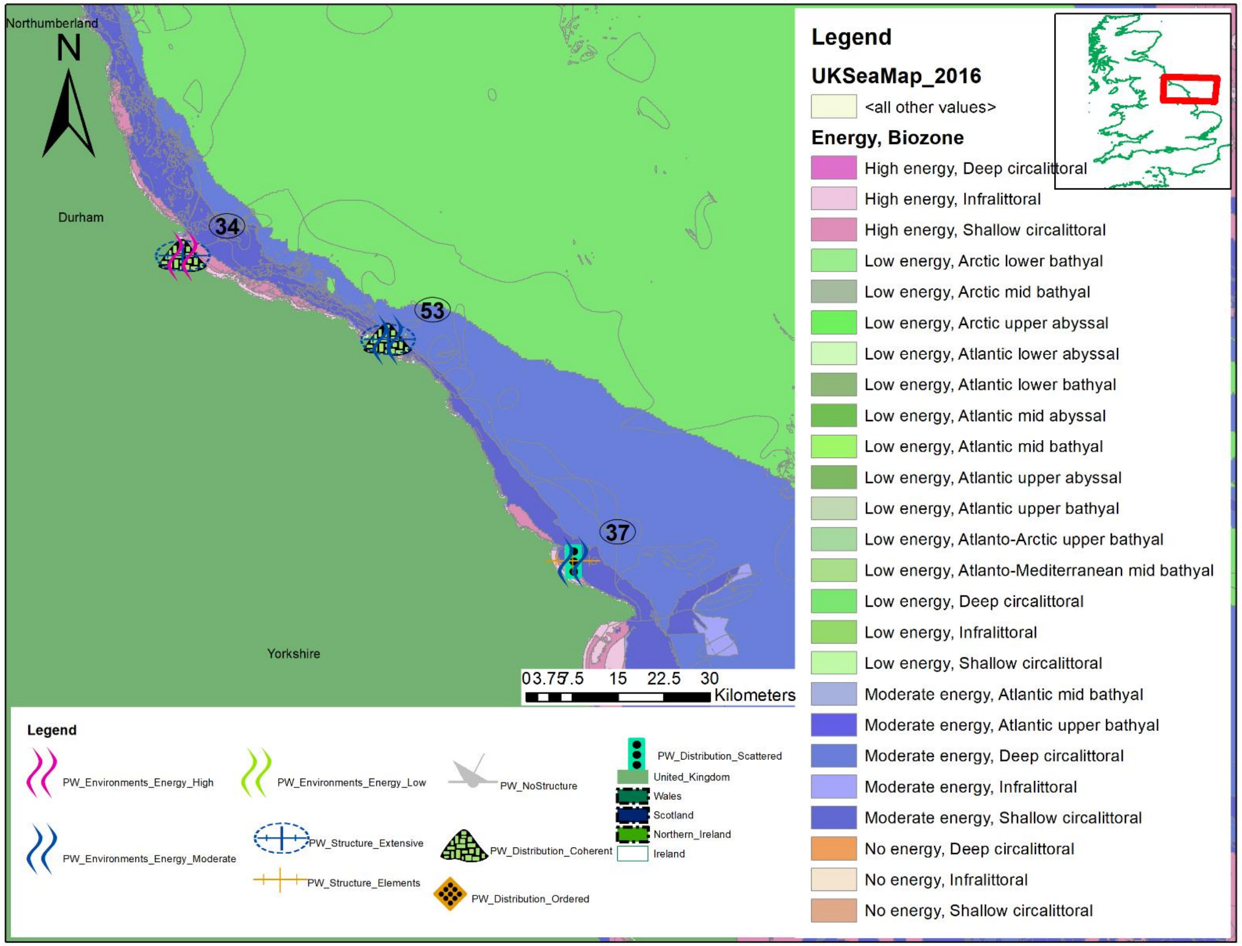


Figure 19. Yorkshire and Durham, England. Energy levels of environments around the UK (High, Moderate and Low) (EMODnet 2018)**. Wrecks plotted from HE** (HE 2018a)**. The author of this thesis created the map with ArcMap 10.5 ®. The site classification was created based on chapter IV.**

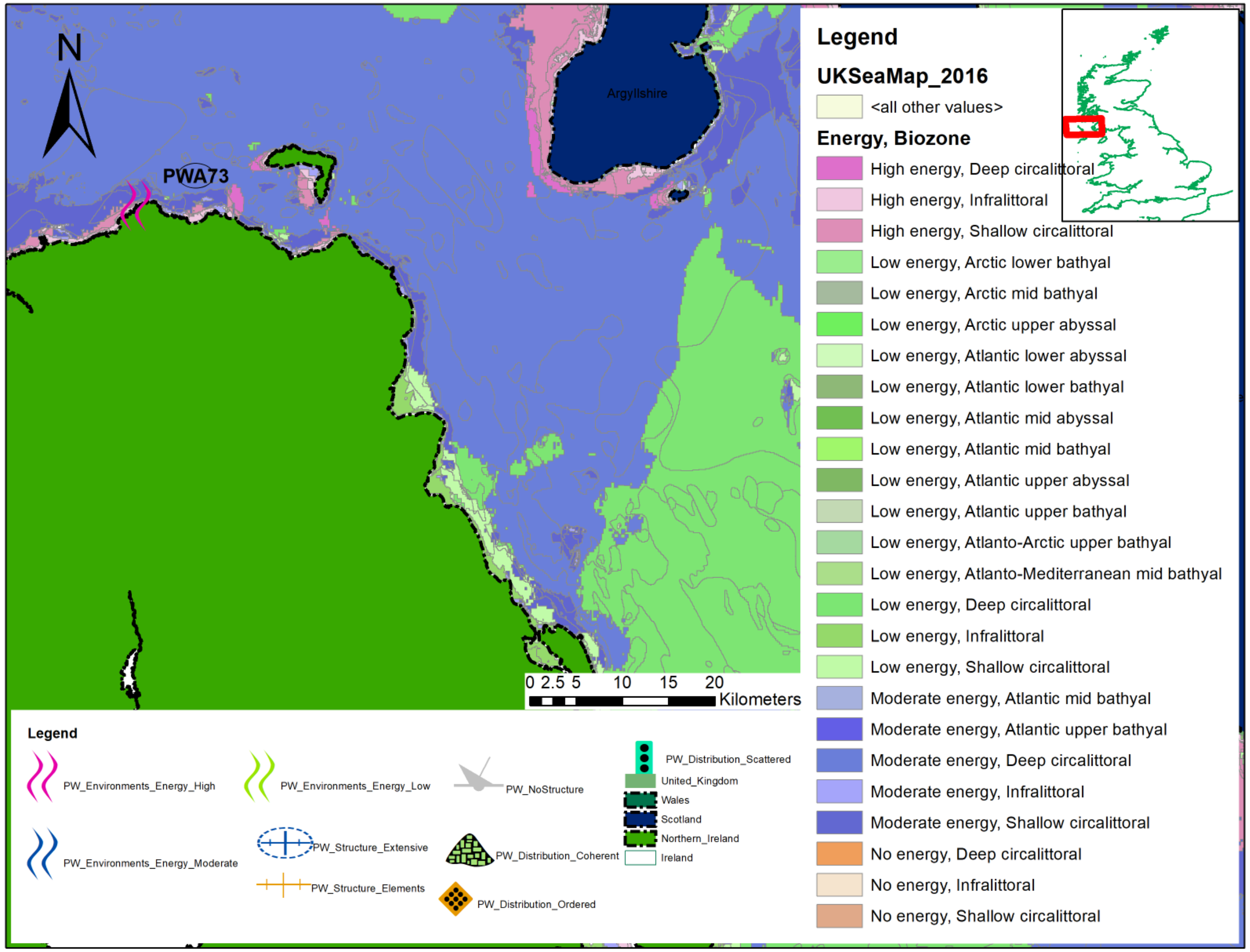


Figure 20. Northern Ireland. Energy levels of environments around the UK (High, Moderate and Low) (EMODnet 2018). **Wrecks plotted from HE, HES, CADW, ODNI** (Geography & Technology 2018; HE 2018a; Historic Environment Scotland 2016; Open Data NI 2018)**. The author of this thesis created the map with ArcMap 10.5 ®. The site classification was created based on chapter IV.**

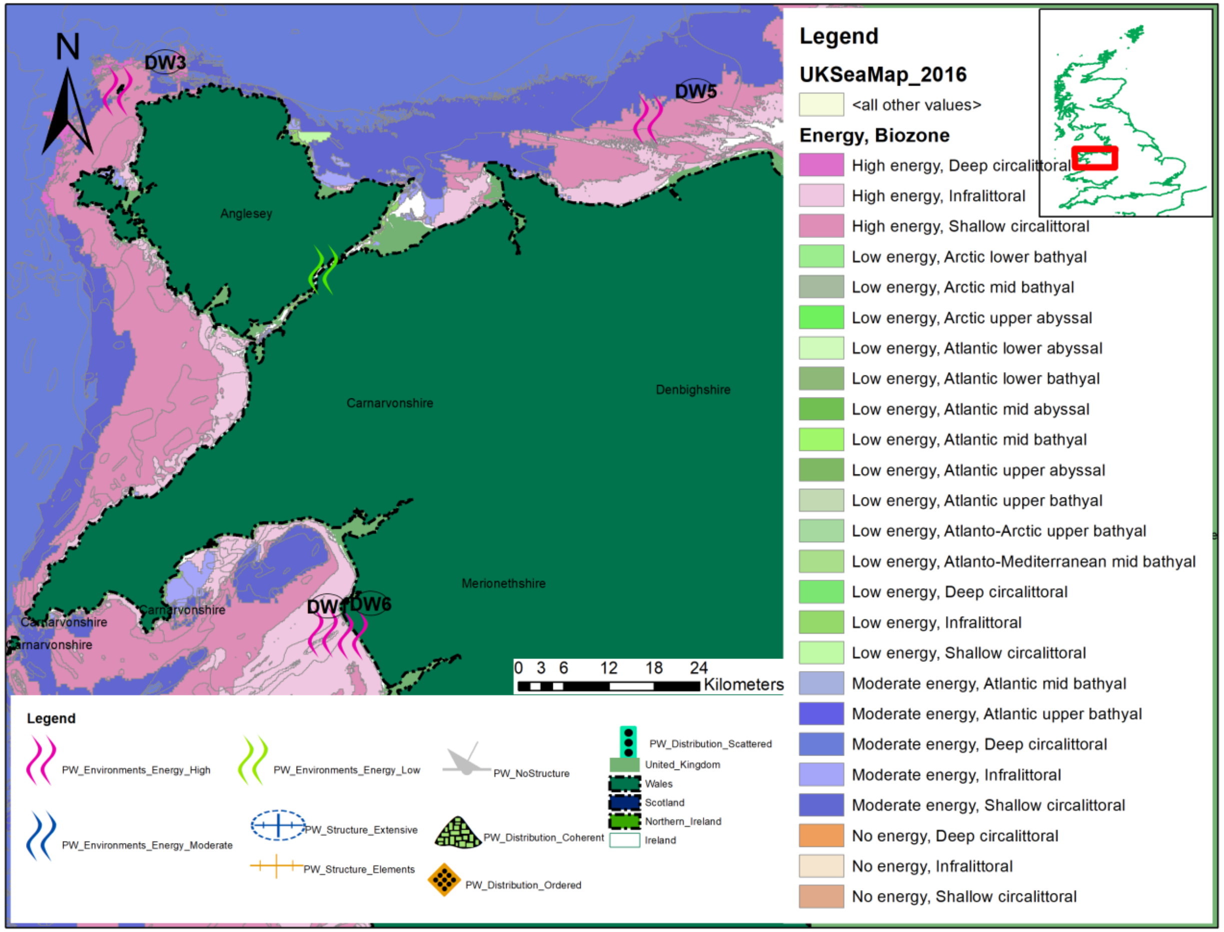


Figure 21. Northern Wales. Energy levels of environments around the UK (High, Moderate and Low) (EMODnet 2018). **Wrecks plotted from CADW. The author of this thesis created the map with ArcMap 10.5 ®. The site classification was created based on chapter IV.**

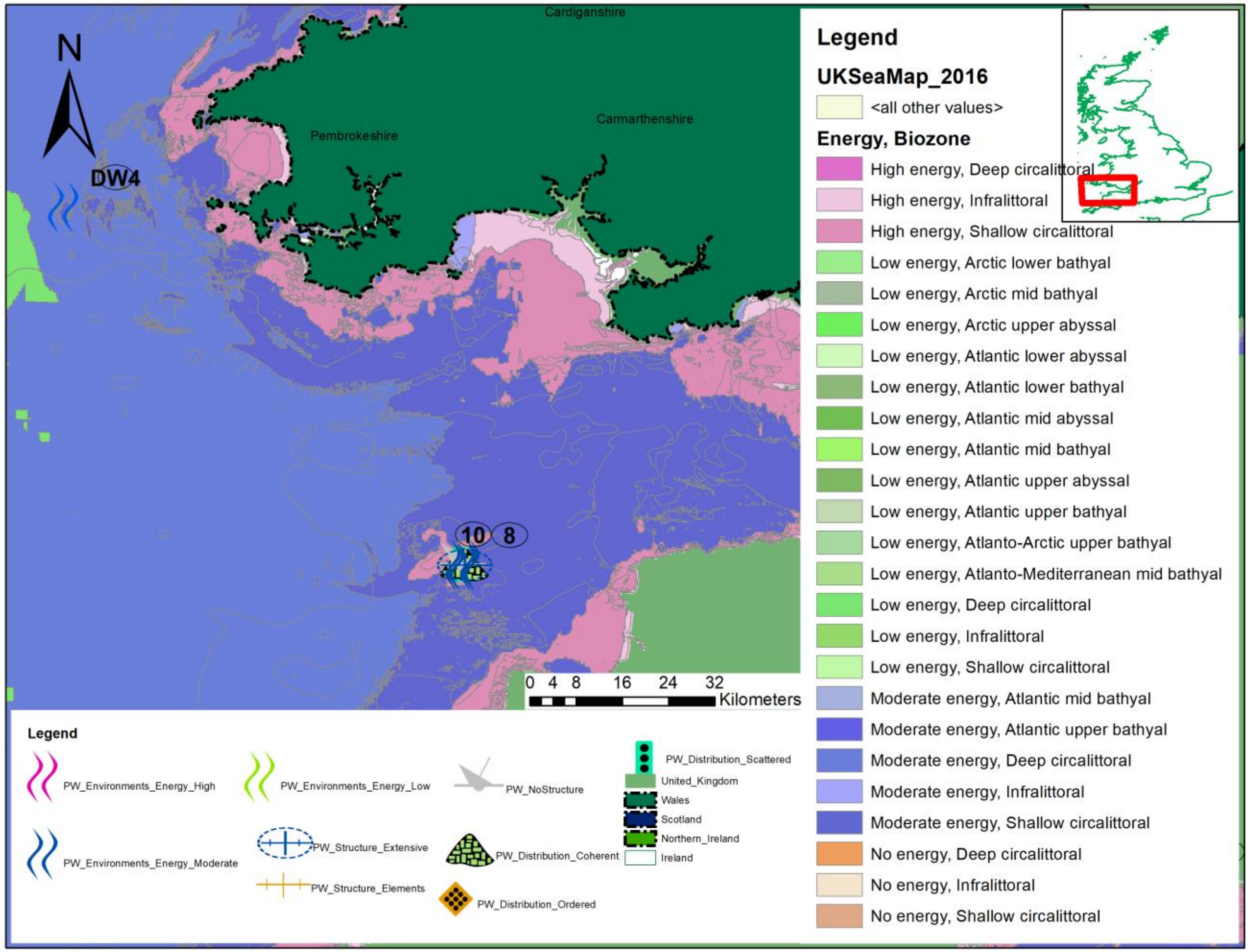


Figure 22. South Wales and Somerset, England. Energy levels of environments around the UK (High, Moderate and Low) (EMODnet 2018)**. Wrecks plotted from HE and CADW** (Geography & Technology 2018; HE 2018b)**. The author of this thesis created the map with ArcMap 10.5 ®. The site classification was created based on chapter IV.**

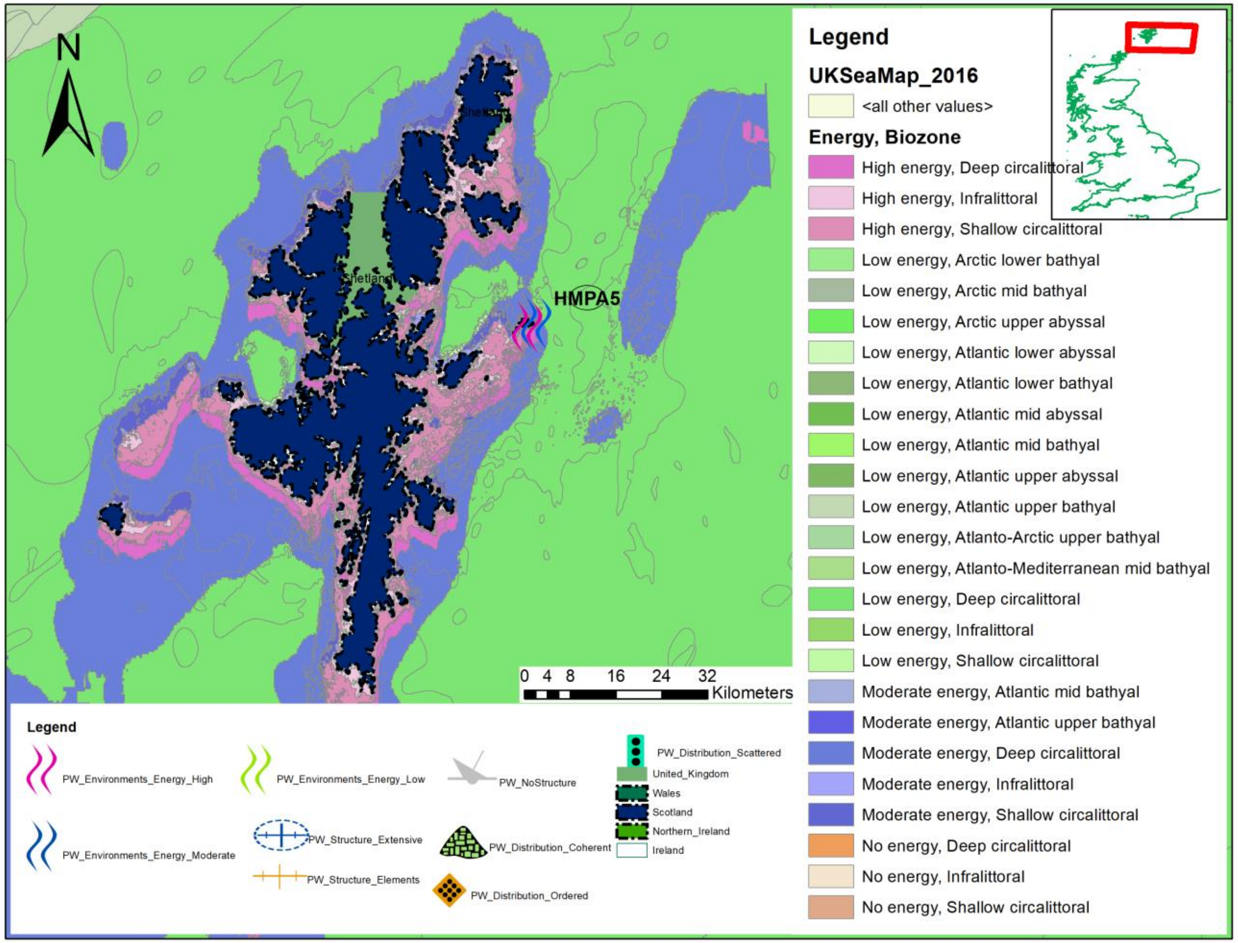


Figure 23. Shetland, Scotland. Energy levels of environments around the UK (High, Moderate and Low) (EMODnet 2018). Wrecks plotted from HES (Historic Environment Scotland 2016). The author of this thesis created based on chapter IV.

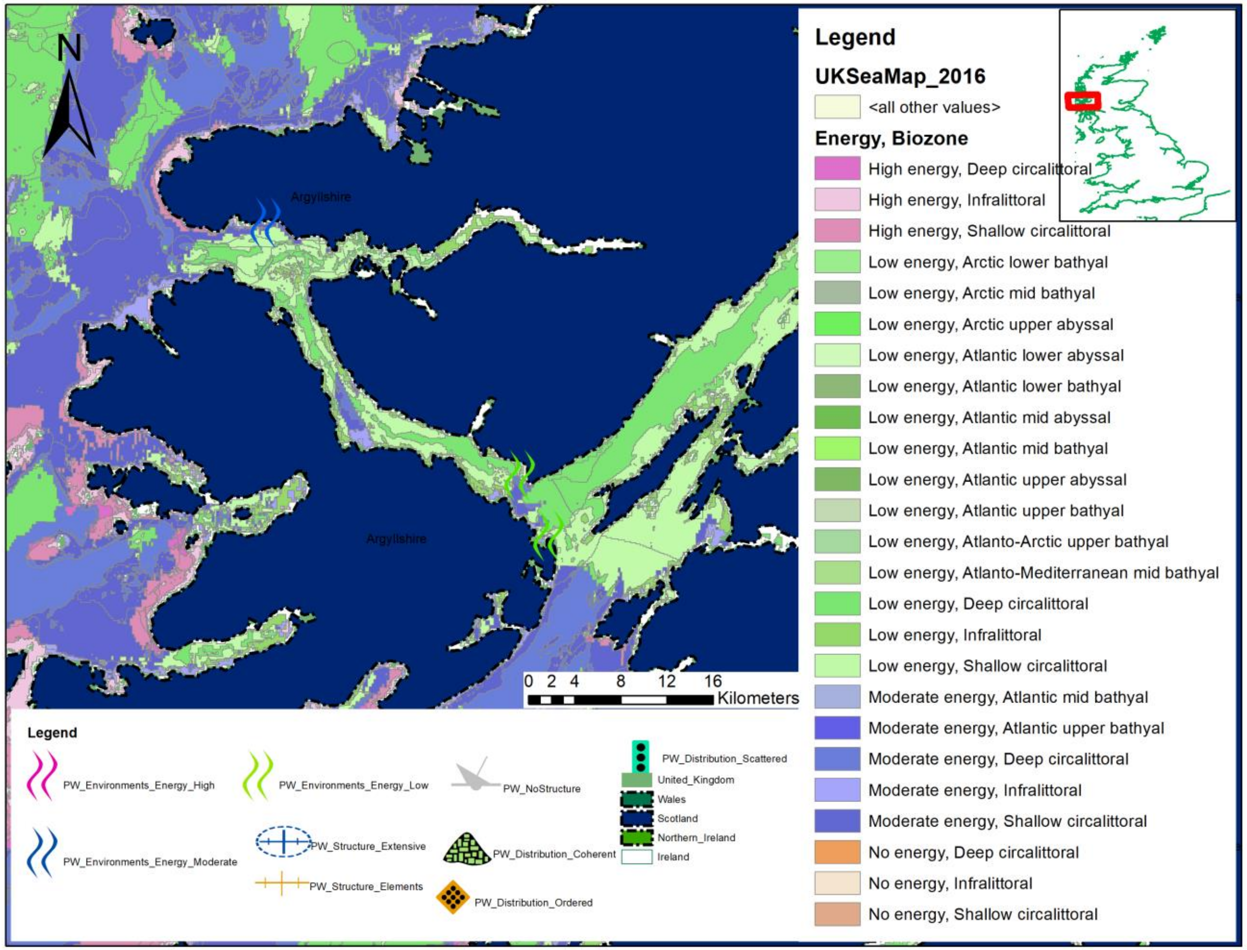


Figure 24. The Sound of Mull, Scotland. Energy levels of environments around the UK (High, Moderate and Low) (EMODnet 2018). Wrecks plotted from HES (Historic Environment Scotland 2016). The author of this thesis created based on chapter IV.

1.6 Early Ships and Boats (ESB), Prehistory to 1840 by WA.

1.6.1 ESB List

The following list and maps contain information based on the WA list of vessels from prehistory to 1840. These boats follow these criteria (Wessex Archaeology 2013):

- Name with a WA ID
- Location (Easting and Northing) in Decimal Degrees WGS84
- Craft Type
    - Designated Wreck (47 records)
    - Undesignated Wrecks (133 records)
    - Boat Burial (6 records)
    - Historic Vessel (28 records)
    - Logboat (4 records)
        - Logboat Findspots[4] (128 records)
    - Other vessel Findspots (28 records)

- Date (Minimum and Maximum)

- Period.
    - Early Prehistoric (500,000-4000 BC)
    - Late Prehistoric (4000-54 BC)
    - Roman (54 BC-AD 410)
    - Post-Roman to Norman Conquest (410 AD-1066)
    - Medieval and Early Tudor (1066-1540)
    - Mid to Late Tudor (1540-1603)
    - Stuart (1603-1714)
    - Hanoverian (1714-1837).

- Survival (Structural Remains)
    - Destroyed (7 records)
    - Broken-up (39 records)
    - Buried (13 records)
    - Dispersed (4 records)
    - Flattened (1 records)
    - Mainly intact (2 records)
    - Partially buried (10 records)
    - Partially intact (36 records)
    - Poor (12 records)
    - Unknown (113 records)
    - Removed (in curation) (71 records)
    - Removed (unknown) (48 records)
    - Extant (28 records)

[4] Parts of vessel, that have been recovered from, or excavated at, a specific location

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
1	305600	524630	Logboat: Branthwaite Boat	Logboat	-2600	-700	Late Prehistoric	Unknown	NO
2	345680	502760	Logboat: River Kent	Logboat	1190	1450	Medieval and Early Tudor	Removed (in curation)	NO
3	402430	566520	Logboat: Shildon Lough	Logboat	-4000	43	Late Prehistoric	Unknown	NO
4	413880	565480	Logboat: Ryton	Logboat	-800	43	Late Prehistoric	Removed (in curation)	NO
5	419620	563810	Logboat: Scotswood Railway Bridge	Logboat	-800	43	Late Prehistoric	Removed (in curation)	NO
6	421400	563200	Logboat: West Dunstan	Logboat	-4000	43	Late Prehistoric	Removed (in curation)	NO
7	435500	557500	Logboat: Hylton	Logboat	-1200	43	Late Prehistoric	Removed (in curation)	NO
8	434300	556630	Logboat: River Wear	Logboat	-1200	-300	Late Prehistoric	Removed (in curation)	NO
9	307700	489900	Logboat: Tarn Bay	Logboat	-4000	43	Late Prehistoric	Unknown	NO
10	319427	464129	Unknown Wreck: Walney Island	Armed Vessel Cargo Vessel	1366	1750	Medieval and Early Tudor Mid to late Tudor Stuart Hanoverian	Unknown	YES
11	340270	418970	Logboat: Martin Mere	Logboat	1066	1540	Medieval and Early Tudor	Removed (in curation)	NO
12	349300	458500	Logboat: Blea Tarn	Logboat	1290	1310	Medieval and Early Tudor	Removed (in curation)	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
13	352600	429100	Logboats: Preston Docks	Logboat	-2600	-700	Late Prehistoric	Removed (in curation)	NO
14	380730	464590	Logboat: Giggleswick Tarn	Logboat	1295	1375	Medieval and Early Tudor	Removed (in curation)	NO
15	435610	423050	Logboat: Stanley Ferry	Logboat	920	1060	Post-Roman	Removed (in curation)	NO
16	499740	407370	Logboat: Brigg Gasworks	Logboat	-934	-734	Late Prehistoric	Removed (in curation)	NO
17	497670	412330	Logboat: Appleby	Logboat	-1180	-1020	Late Prehistoric	Removed (in curation)	NO
18	329300	302800	Logboat: Marton Pool	Logboat	-800	43	Late Prehistoric	Removed (in curation)	NO
19	333450	322250	Logboat: Weir Brook	Logboat	-500000	410	Early Prehistoric Late Prehistoric Roman	Removed (in curation)	NO
20	343480	330790	Logboat: Whattall Moss	Logboat	-2600	43	Late Prehistoric	Removed (in curation)	NO
21	359710	350390	Logboat: Baddiley Mere	Logboat	-800	43	Late Prehistoric	Removed (in curation)	NO
22	353500	351500	Logboat: Cholmondeley Castle	Logboat	-800	43	Late Prehistoric	Unknown	NO
23	357320	367680	Logboat: Oakmere	Logboat	43	1540	Post-Roman Medieval and Early Tudor	Removed (in curation)	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
25	367186	303383	Logboat: Ironbridge	Canoe/Logboat	-500000	410	Early Prehistoric Late Prehistoric Roman Post-Roman Medieval	Removed (in curation)	NO
26	360140	386500	Logboats: Warrington	Logboat	900	1075	Early Tudor	Removed (in curation)	NO
27	375300	396810	Logboat: Barton	Logboat	965	1095	Post-Roman Medieval and Early Tudor	Removed (in curation)	NO
28	390400	349080	Logboat: Hulton Fishponds	Logboat	1066	1540	Medieval and Early Tudor	Removed (in curation)	NO
29	510000	428800	Logboat: Hull Guild Hall	Logboat	1501	1600	Medieval and Early Tudor to Late Tudor	Removed (in curation)	NO
30	335450	165670	Findspot: Congresbury Moor	Craft	260	440	Roman	Removed (Unknown)	NO
31	332060	161970	Findspot: Weston-super-Mere	Craft	-800	1860	Late Prehistoric	Destroyed	NO
32	349800	141730	Logboat: Glastonbury Lake Village	Logboat	-200	43	Late Prehistoric	Removed (in curation)	NO
33	342300	141070	Logboat: Shapwick	Logboat	-455	-215	Late Prehistoric	Removed (in curation)	NO
34	452080	111810	Logboat: Curdridge Creek	Logboat	-500000	410	Early Prehistoric Late Prehistoric Roman	Removed (in curation)	NO
35	489500	187500	Logboat: Bourne End Station	Logboat	-800	410	Late Prehistoric Roman	Unknown	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
36	497500	176500	Logboat: Windsor	Logboat	-800	43	Late Prehistoric	Unknown	NO
37	440710	391480	Logboat: Chapel Flat Dyke	Logboat	-1650	-1350	Late Prehistoric	Removed (in curation)	NO
38	455200	335980	Logboats: River Trent	Logboat	-2600	-700	Late Prehistoric Roman Post-Roman	Removed (in curation)	NO
39	462980	339560	Logboats: Holme Pierrepoint	Logboat	-340	-120	Late Prehistoric Roman	Unknown	NO
40	480500	389500	Logboat: Gainsborough	Logboat	-4000	43	Late Prehistoric	Unknown	NO
41	406600	265300	Logboat: Ipsley	Logboat	-900	-700	Late Prehistoric	Removed (in curation)	NO
42	508950	371200	Logboat: Short Ferry	Logboat	-946	-746	Late Prehistoric	Removed (Unknown)	NO
43	509600	371500	Logboats: Stainfield	Logboat	-800	43	Late Prehistoric	Unknown	NO
44	515500	352500	Logboat: North Kyme	Logboat	-2600	-700	Late Prehistoric	Unknown	NO
45	519190	298160	Logboat: River Nene	Logboat	-1200	-300	Late Prehistoric	Removed (Unknown)	NO
46	539500	285500	Logboat: Chatteris	Logboat	-2600	-700	Late Prehistoric	Unknown	NO
47	531720	282660	Logboat: Warboys	Logboat	-10000	-700	Early Prehistoric Late Prehistoric	Removed (Unknown)	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
48	544500	277500	Logboat: North Fen	Logboat	-2600	-700	Late Prehistoric	Removed (Unknown)	NO
49	503330	108190	Logboat: Burpham	Logboat	-800	410	Late Prehistoric Roman	Buried	NO
50	502850	107800	Logboat: Burpham	Logboat	-800	410	Late Prehistoric Roman	Removed (in curation)	NO
51	504580	117000	Logboats: River Arun	Logboat	245	345	Roman	Removed (in curation)	NO
52	501870	113300	Logboats: Amberley	Logboat	570	710	Roman Post-Roman	Removed (in curation)	NO
53	506320	159880	Logboat: Wisley	Logboat	1100	1300	Medieval and Early Tudor	Removed (in curation)	NO
54	531670	180810	Findspot: Blackfriars Ship I	Cargo Vessel	140	160	Roman	Removed (in curation)	NO
55	537370	199990	Logboat: Waltham Cross	Logboat	-4000	43	Late Prehistoric	Removed (Unknown)	NO
56	537980	198450	Logboat: River Lea	Logboat	860	1060	Post-Roman	Removed (in curation)	NO
57	549500	179200	Logboat: Belvedere Station	Logboat	-4000	-1600	Late Prehistoric	Unknown	NO
58	542700	180630	Logboat: Royal Albert Docks	Logboat	43	410	Roman	Removed (in curation)	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
59	562680	101030	Findspot: Eastbourne	Craft	1101	1400	Medieval and Early Tudor	Removed (in curation)	NO
60	572870	106780	Findspot: Bexhill	Coracle	410	1066	Post-Roman	Unknown	NO
61	146100	29200	Logboat: Tolcarne	Logboat	43	410	Roman	Unknown	NO
62	166500	40500	Logboat: Tuckingmill	Logboat	-2600	-700	Late Prehistoric	Unknown	NO
63	255500	58500	Logboat: Newnham Park	Logboat	43	410	Roman	Unknown	NO
64	403300	87800	Logboat: Poole Harbour	Logboat	-345	-245	Late Prehistoric	Removed (in curation)	NO
65	423800	562800	Logboat: Skinner Burn	Logboat	-4000	1066	Late Prehistoric Roman Post-Roman	Unknown	NO
66	430230	85320	HMS *Pomone* (Alum Bay Wreck)	Fifth Rate Warship *Frigate*	1805	1811	Hanoverian	Partially Intact	NO
67	429000	84810	*Campen*	Armed Cargo Vessel Cargo Vessel, Yacht, East Indiaman	1627	17/10/1627	Stuart	Poor	NO
68	429130	84290	Findspot: The Needles	Warship	270	290	Roman	Removed (Unknown)	NO
69	462590	95730	HMS *Royal George*	First rate Warship	1756	29/08/1782	Hanoverian	Dispersed	NO
70	646746	152625	*Britannia*	Armed Cargo Vessel Cargo East Indiaman	1806	1809	Hanoverian	Partly Buried	YES
71	277143	34912	HMS *Crocodile*	Sixth Rate Warship	1781	09/05/1784	Hanoverian	Broken Up	YES

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
72	268713	38079	*Dragon*	Armed Cargo Vessel Cargo West Indiaman	1757	22/08/1757	Hanoverian	Unknown	YES
73	267095	39170	HMS *Ramillies*	Second rate Warship	1664	15/02/1760	Stuart Hanoverian	Broken Up	YES
74	289046	50299	Kingswear Castle Cannon Site	Privateer Warship	1660	1680	Stuart	Broken Up	NO
75	241342	141198	HMS *Weazle*	Warship *Brig/ Sloop*	1783	10/02/1799	Hanoverian	Unknown	YES
76	373049	75302	Portland Stone Sailing Barge	Armed Cargo Vessel Cargo Vessel	1733	1766	Hanoverian	Partially Intact	NO
77	374500	287500	Logboat: River Severn	Logboat	-4000	410	Late Prehistoric Roman	Removed (in curation)	NO
78	441700	513100	Logboat: Yarm	Logboat	-500000	43	Late Prehistoric Early Prehistoric	Removed (Unknown)	NO
79	449500	520500	Logboat: Middlesborough	Logboat	-500000	43	Late Prehistoric Early Prehistoric	Unknown	NO
80	95800	15870	*Juno*	Cargo Vessel *Barque*	1782	10/01/1797	Hanoverian	Unknown	YES
81	87778	11442	Designated Wreck: HMS Colossus	Third rate Warship	1787	10/12/1798	Hanoverian	Poor	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
82	83790	6160	*Princess Maria*	Armed Cargo Vessel Cargo East Indiaman	1682	1686	Stuart	Partially Intact	YES
83	92070	9090	Unknown Wreck: Gilstone Rock	Cargo Vessel Vessel Transport Vessel	1689	10/11/1689	Stuart	Unknown	YES
84	83440	4580	HMS *Association*	Second rate Warship	1696	23/10/1707	Stuart	Broken Up	YES
85	80926	6177	HMS *Romney*	Forth rate Warship	1694	22/10/1707	Stuart	Broken Up	YES
86	87250	7850	HMS *Firebrand*	Fire Ship Warship	1694	23/10/1707	Stuart	Partially Intact	NO
87	84780	8200	*Hollandia*	Armed Cargo Vessel Cargo East Indiaman	1742	13/07/1743	Hanoverian	Unknown	YES
88	392500	86500	Logboat: River Frome	Logboat	-4000	43	Late Prehistoric	Unknown	NO
89	468440	390010	Logboat: Mattersey Thorpe	Logboat	380	540	Roman Post- Roman	Removed (in curation)	NO
90	623960	135986	*Grantham*	Armed Cargo Vessel Cargo East Indiaman	1727	1744	Hanoverian	Unknown	YES
91	397940	76210	*Halsewell*	Armed Cargo Vessel Cargo East Indiaman Passenger Ship	1786	06/01/1786	Hanoverian	Broken Up	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
92	371135	78156	*Earl of Abergavenny*	Armed Cargo Vessel Cargo East Indiaman Passenger ship	1789	05/02/1805	Hanoverian	Partly Buried	NO
93	404639	79063	*Fanny*	Coaster Sloop	1793	01/02/1793	Hanoverian	Poor	YES
94	643448	147578	*Britannia*	Cargo Vessel	1806	1809	Hanoverian	Unknown	YES
95	423450	637598	Gunrocks Wreck	Armed Cargo Vessel Cargo	1650	1715	Stuart	Poor	NO
96	589857	180957	Designated Wreck: *London* (*King*)	Craft Warship	1636	1799	Stuart Hanoverian	Partially Intact	NO
97	590282	180988	Designated Wreck: *London*	Second rate ship of the Line	1656	07/03/1665	Stuart	Broken Up	NO
98	534200	428200	Logboat: Owthorne	Logboat	-4000	43	Late Prehistoric	Unknown	NO
99	534500	428500	Logboat: Owthorne	Advice Boat	1715	1735	Hanoverian	Unknown	NO
100	481943	94547	*Eagle*	Sixth rate ship of the line warship	1696	27/11/1703	Stuart	Partially Intact	YES
101	652247	277268	*Royal James*	First rate ship of the line Warship	1671	28/05/1672	Stuart	Unknown	YES
103	168124	13029	*Ospra*	Cargo Vessel *Brigantine*	1832	06/05/1832	Hanoverian	Broken Up	YES
104	166379	17893	*Santo Christo de Castello*	Cargo Vessel *Galleon*	1588	1588	Medieval and Early Tudor	Unknown	NO
105	136883	20135	Unknown Wreck: British Storage Hulk	Storage *Hulk*	1806	07/03/1806	Hanoverian	Unknown	YES

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
107	181726	20808	HMS *Primrose*	Warship *Brig/Sloop*	1807	22/01/1809	Hanoverian	Broken Up	YES
108	164169	23781	HMS *Anson*	Third rate Warship	1781	29/12/1807	Hanoverian	Broken Up	YES
109	80200	9510	Unknown Wreck: Crim Rocks	Warship	1600	1700	Stuart	Broken Up	NO
110	532000	180800	Findspot: Blackfriars Ship III	Barge Cargo vessel	1485	1600	Medieval and Early Tudor	Unknown	NO
111	166730	18660	*Santo Christo de Castello*	Cargo Vessel *Carrack*	1667	03/10/1667	Stuart	Poor	NO
112	569500	109500	Logboat: Hooe Level	Logboat	-500000	410	Early Prehistoric Late Prehistoric Roman	Unknown	NO
113	539060	101230	*Diana*	Brig Cargo vessel	1803	26/05/1803	Hanoverian	Broken Up	YES
114	532000	180800	Findspot: Blackfriars Ship IV	Cargo vessel	1066	1600	Medieval and Early Tudor	Unknown	NO
115	297680	146783	*Lamb*	Cargo vessel Packet/passenger vessel	1736	21/02/1736	Hanoverian	Unknown	YES
116	213060	145770	*Jenny*	Cargo vessel Schooner	1797	1797	Hanoverian	Unknown	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
117	435775	90079	Designated Wreck: Yarmouth Roads	Cargo Vessel *Carrack*	1550	1632	Medieval and Early Tudor-Stuart	Partially Intact	NO
118	406140	84680	Designated Wreck: Studland Bay	Armed Cargo Vessel Cargo	1500	1525	Medieval and Early Tudor	Partially Intact	NO
119	167669	13447	Designated Wreck: Rill Cove	Armed Cargo Vessel Cargo	1600	1632	Medieval and Early Tudor-Stuart	Broken Up	NO
120	533280	102945	Designated Wreck: Brighton Marina	Craft	1500	31/12/1599	Medieval and Early Tudor	Partially Intact	NO
121	428917	84810	Designated Wreck: HMS Assurance (The Needles)	Firth rate Warship	1747	24/04/1753	Hanoverian	Broken Up	NO
122	428917	84810	Designated Wreck: HMS *Pomone(The Needles)*	Firth rate *Frigate* Warship	1805	14/10/1811	Hanoverian	Partially Intact	NO
123	480560	95360	Designated Wreck: *Hazardous*	Fourth rate Warship	1698	19/11/1706	Stuart	Broken Up	NO
124	165640	20620	Designated Wreck: *Schiedam*	Armed Cargo Vessel Cargo East Indiaman *Fluit*	1683	1684	Stuart	Broken Up	NO
125	467930	93770	Designated Wreck: HMS Invincible	Third rate Warship	1744	19/02/1758	Hanoverian	Partially Intact	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
126	214351	146301	Designated Wreck: Gull Rock	Armed Cargo Vessel Cargo *Carrack*	1400	1599	Medieval and Early Tudor	Unknown	NO
127	260660	46630	Designated Wreck: Erme Ingot	Craft	-2600	1000	Late Prehistoric Roman Post-Roman	Unknown	NO
128	577915	108159	Designated Wreck: *Amsterdam*	Armed Cargo Vessel Cargo East Indiaman	1748	1749	Hanoverian	Partially Buried	NO
129	644689	158640	Designated Wreck: *Stirling Castle*	Third rate Warship	1679	27/11/1703	Stuart	Broken Up	NO
130	644190	157138	Designated Wreck: Restoration and *Mary*	Third rate Warship	1678	27/11/1703	Stuart	Partially Intact	NO
131	644192	156860	*Designated Wreck: Northumberland*	Third rate Warship	1679	27/11/1703	Stuart	Broken Up	NO
132	634138	141759	Designated Wreck: Langdon Bay	Cargo vessel	-1600	-1200	Late Prehistoric	Broken Up	NO
133	589770	113620	Designated Wreck: *Anne*	Third rate Warship *Frigate*	1678	05/07/1690	Stuart	Broken Up	NO
134	450129	110565	Designated Wreck: *Grace Dieu*	Warship *Carrack*	1418	07/01/1439	Medieval and Early Tudor	Partially Buried	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
135	645130	150440	Designated Wreck: Admiral Gardner	Armed Cargo Vessel Cargo East Indiaman	1797	24/01/1809	Hanoverian	Buried	NO
136	80926	6176	Designated Wreck: Tearing Ledge	Third rate Warship	1707	22/10/1707	Stuart	Partially Intact	NO
137	294720	73220	Designated Wreck: Church Rocks	Armed Cargo Vessel Cargo *Galley*	1567	1599	Medieval to late Tudor	Partially Intact	NO
138	248725	53519	Designated Wreck: Cattewater Wreck	Armed Cargo Vessel Cargo	1530	31/12/1539	Medieval and Early Tudor	Partially Intact	NO
139	89113	9535	Designated Wreck: Bartholomew Ledges	Armed Cargo Vessel Cargo	1533	1624	Medieval to late Tudor-Stuart	Unknown	NO
140	164900	22640	Designated Wreck: *St.Anthony*	Armed Cargo Vessel Cargo *Carrack*	1527	19/01/1527	Medieval and Early Tudor	Partially Intact	NO
141	169390	11397	Designated Wreck: *Royal Anne*	Firth rate Warship *Galley*	1709	10/11/1721	Hanoverian	Poor	NO
142	243390	47889	Designated Wreck: Coronation Offshore	Second rate Warship	1685	03/09/1691	Stuart	Partially Intact	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
143	243900	48600	Designated Wreck: Coronation Inshore	Second rate Warship	1685	03/09/1691	Stuart	Broken Up	NO
144	260930	47099	Designated Wreck: Erme Estuary	Craft	1490	31/12/1750	Medieval to late Tudor-Stuart Hanoverian	Partially Intact	NO
145	83460	5730	*The Nancy Packet*	Armed Cargo Vessel Cargo East Indiaman Packet/passenger vessel	1783	15/02/1810	Hanoverian	Broken Up	YES
146	173700	53201	Designated Wreck: *Hanover*	Armed Cargo Vessel Cargo *Brigantine*	1757	06/12/1763	Hanoverian	Unknown	NO
147	648439	267908	Designated Wreck: Dunwich Bank	Armed Cargo Vessel Cargo Warship	1536	1699	Mid to late Tudor	Broken Up	NO
148	275531	36147	Designated Wreck: Salcombe Cannon	Crago Vessel Corsair/Privateer Slave Ship *Xebec*	1636	31/12/1640	Stuart	Partially Intact	NO
149	463360	95830	Designated Wreck: *Mary Rose*	Warship	1509	19/07/1545	Mid to late Tudor	Removed (in curation)	NO
150	181640	20160	*Ocean*	Cargo Vessel	1829	04/01/1829	Hanoverian	Unknown	YES
151	358140	78970	*Hope*	Cargo Vessel	1749	16/01/1749	Hanoverian	Buried	YES
152	632010	141280	Findspot: The Dover Boat	Craft	-1400	-1300	Late Prehistoric	Removed (in curation)	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
153	634720	157630	Logboat: Ramsgate	Logboat	970	1160	Post-Roman Medieval to early Tudor	Unknown	NO
154	246520	52420	*Catharina von Flensburg*	Armed Cargo Vessel Cargo *Brigantine*	1782	10/12/1786	Hanoverian	Partially Intact	YES
156	452990	529570	Designated Wreck: Seaton Carew	Cargo Vessel *Brig*/*Collier*	1700	31/12/1799	Stuart Hanoverian	Partially Intact	NO
157	88433	11815	Designated Wreck: HMS Colossus	Third rate Warship	1798	10/12/1798	Hanoverian	Partially Intact	NO
158	377260	320130	Findspot: North West Wetlands Survey	Craft	903	31/12/1207	Post-Roman Medieval to early Tudor	Unknown	NO
159	625257	186158	Designated Wreck: South Edinburgh Channel	Armed Cargo Vessel Cargo East Indiaman	1733	1832	Hanoverian	Buried	NO
160	527680	103660	Unknown Wreck: Roman Tiles	Cargo vessel	43	410	Roman	Unknown	YES
161	515819	478800	Designated Wreck: Filey Bay	Cargo vessel Privateer *Coaster Frigate*	1779	1779	Hanoverian	Partially Intact	NO
162	423730	638370	*Pearle*	*Brig*/*Barquentine*/*Schooner*/*Snow*	1717	26/01/1741	Hanoverian	Unknown	YES
163	470188	104076		Logboat	400	600	Roman Post-Roman	Removed (in curation)	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
			Logboat: Langstone Harbour						
164	148002	27243	Low Lee Ledges	Armed Cargo Vessel Cargo East Indiaman	1600	31/12/1632	Mid to late Tudor Stuart	Poor	NO
165	405193	85098	Designated Wreck: Swash Channel	Armed Cargo Vessel Cargo	1630	1699	Stuart	Partially Intact	NO
166	345034	89734	Designated Wreck: West Bay	Armed Cargo Vessel Cargo	1627	31/12/1750	Stuart to Hanoverian	Partially Intact	NO
167	165690	20340	Dollar Wreck	Cargo vessel	1770	31/12/1779	Hanoverian	Partially Intact	YES
168	649360	158897	Designated Wreck: *Rooswijk*	Armed Cargo Vessel Cargo East Indiaman	1737	30/12/1739	Hanoverian	Broken Up	NO
169	473435	96651	HMS *Impregnable*	Second rate Warship	1786	19/10/1799	Hanoverian	Unknown	NO
170	178496	16211	*Brielle*	Fourth rate Warship	1786	22/12/1791	Hanoverian	Unknown	YES
171	455128	66847	*Minerva*	Armed Cargo Vessel Cargo	1816	01/09/1816	Hanoverian	Broken Up	YES
172	83479	5901	Unknown Wreck: Santaspery Neck	Craft	1790	1810	Hanoverian	Unknown	YES

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
173	532810	179924	Wreck: New Guy's House	*Barge*	167	200	Roman	Partially Buried	NO
174	158070	27580	*Le Kateryn van Arnude*	Cargo vessel	1300	1499	Medieval to Early Tudor	Buried	YES
175	249796	46988	Unknown Wreck: Mewstone	Armed Cargo Vessel Cargo	1733	31/12/1799	Hanoverian	Unknown	NO
176	289927	59873	HMS *Venerable*	Third rate Warship	1784	24/11/1804	Hanoverian	Broken Up	YES
177	289765	60124	HMS *Savage*	Warship *Sloop*	1762	28/02/1762	Hanoverian	Unknown	YES
178	546945	99158	Seaford Guns Site	Armed Cargo Vessel Cargo	1500	1809	Medieval to late Tudor-Stuart	Unknown	YES
179	644595	158682	Unknown Wreck: Goodwin Sands	Cargo vessel	1700	31/12/1799	Stuart to Hanoverian	Unknown	NO
180	644617	158423	Unknown Wreck: Goodwin Sands	CARGO VESSEL	1700	1799	Stuart to Hanoverian	Broken Up	NO
181	295940	74090	*Bellona*	Armed Cargo *Brig*	1779	05/09/1779	Hanoverian	Broken Up	YES
182	88000	16000	Unknown Wreck: Gimble Point	Cargo vessel	1300	1540	Medieval to early Tudor	Unknown	NO
183	91245	13166	Pendrathen Wreck	Armed Cargo Vessel Cargo	1700	31/12/1766	Stuart to Hanoverian	Partially Intact	NO
184	169200	11550	Quadrant Wreck	Warship	1704	1733	Stuart to Hanoverian	Poor	YES

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
185	649280	195210	Unknown Wreck: Knock Deep	Armed Cargo Vessel Cargo East Indiaman	1800	31/12/1833	Hanoverian	Removed (Unknown)	YES
187	656666	274550	*Royal James*	Warship	1600	31/12/1699	Mid to late Tudor-Stuart	Removed (Unknown)	NO
188	532048	180802	Findspot: Blackfriars II	Cargo Vessel *Barge*	1650	1674	Stuart	Destroyed	NO
189	530670	179780	Findspot: County Hall	*Hulk*	296	300	Roman	Removed (Unknown)	NO
190	617220	174430	Pudding Pan Wreck	Cargo vessel	167	200	Roman	Unknown	NO
191	423910	638260	*Forfarshire*	Cargo vessel Paddle Steamer Passenger vessel	1838	07/09/1838	Hanoverian	Broken Up	YES
192	193040	36680	*Scarborough*	Privateer	1650	1696	Stuart	Unknown	NO
193	182840	35050	Findspot: Carrick Roads	Cargo vessel	1720	31/12/1799	Hanoverian	Removed (in curation)	NO
194	341220	353790	Unknown Wreck: Farndon	Craft	1640	1699	Mid to late Tudor Stuart	Unknown	NO
195	384890	360540	Logboat: Astbury	Logboat	410	1065	Post-Roman	Removed (in curation)	NO
198	360700	386390	Logboat: Warrington Logboat 5	Logboat	410	1065	Post-Roman	Removed (Unknown)	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
199	361170	387720	Logboat: Warrington Logboat 4	Logboat	410	1065	Post-Roman	Unknown	NO
200	363620	388180	Logboat: Warrington Logboat 8	Logboat	410	1065	Post-Roman	Removed (Unknown)	NO
201	361100	387700	Logboats: Warrington Logboats 9 and 10	Logboat	410	1065	Post-Roman	Unknown	NO
202	361030	387730	Logboat: Warrington Logboat 3	Logboat	410	1065	Post-Roman Medieval to early Tudor	Removed (Unknown)	NO
203	359850	386570	Logboat: Warrington Logboat 7	Logboat	410	1065	Post-Roman Medieval to early Tudor	Removed (Unknown)	NO
204	362000	388000	Logboat: Warrington Logboat	Logboat	410	1065	Post-Roman	Unknown	NO
205	360140	386500	Logboat: Warrington Logboat 1	Logboat	410	1065	Post-Roman	Removed (Unknown)	NO
206	360660	386400	Logboat: Warrington Logboat 2	Logboat	410	1065	Post-Roman Medieval to early Tudor	Removed (Unknown)	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
207	363100	387550	Logboat: Warrington Logboat 6	Logboat	410	1065	Post-Roman Medieval to early Tudor	Unknown	NO
208	358300	387100	Logboat: Warrington Logboat 11	Logboat	410	1090	Post-Roman Medieval to early Tudor	Unknown	NO
209	601500	212500	Findspot: West Mersea	Craft *Essex Skiff*	1750	1890	Hanoverian	Removed (Unknown)	NO
212	592445	195915	Findspot: River Crouch	Craft	-2000	-701	Late Prehistoric	Removed (Unknown)	NO
214	455750	93060	Findspot: Fishbourne Beach ('Bulls Bay')	Craft	1600	1650	Mid to late Tudor Stuart	Removed (in curation)	NO
215	462300	95760	HMS *Boyne*	Second rate Warship	1790	04/05/1795	Hanoverian	Dispersed	YES
217	616333	181463	Princes Channel Wreck	Armed cargo vessel	1574	1600	Mid to late Tudor	Removed (in curation)	NO
218	608000	165000	Logboat: Seasalter	Logboat	-500000	42	Early Prehistoric Late Prehistoric Roman	Removed (Unknown)	NO
219	632700	170400	Logboat: St.Mildred's Bay	Logboat	-4000	-1501	Late Prehistoric	Buried	YES
220	634500	170900	Unknown Wrecks: Nayland Rock	Craft	1066	1900	Medieval to late Tudor	Unknown	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
221	576100	170300	*Charles V*	Gaurship	1667	10/06/1667	Stuart	Unknown	NO
222	590866	175216	Old ships sunk with design to make new docks at Sheerness	*Hulk*	1725	1725	Mid to late Tudor Stuart Hanoverian	Unknown	NO
224	609128	165798	Unknown Wreck: Old Smack	*Smack*	1770	1770	Hanoverian	Unknown	NO
225	626200	176800	*Hindostan*	Armed Cargo Vessel Cargo East Indiaman	1796	1803	Hanoverian	Destroyed	NO
229	369845	336805	Logboat: River Tern	Logboat	-4000	1400	Post-Roman Medieval to early Tudor	Removed (in curation)	NO
230	329555	302975	Logboat: Marton Pool	Logboat	-500000	1840	Unknown	Removed (in curation)	NO
231	350635	307855	Logboat: Shomere Pool	Logboat	-500000	1840	Unknown	Unknown	NO
233	373885	321645	Logboat: Chetwynd Park	Logboat	-2600	-700	Late Prehistoric	Removed (in curation)	NO
235	340000	327500	Logboat: Bagley Moor	Logboat	-500000	1840	Unknown	Removed (Unknown)	NO
238	592400	165900	Logboat: Murston Marshes	Logboat	-500000	42	Early Prehistoric Late Prehistoric Roman	Destroyed	NO
242	300270	507050	Logboat: Ehenside Tarn	Logboat	-4000	-55	Late Prehistoric	Removed (in curation)	NO
243	355930	497900	Logboat: Whinfell Tarn	Logboat	1540	1900	Mid to late Tudor Stuart	Removed (Unknown)	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
							Hanoverian		
245	275950	36150	Designated Wreck: Moor Sand	Craft	-2500	-800	Late Prehistoric	Unknown	NO
246	286370	72660	Findspot: Kingsteignton	*Galley*	1066	1539	Medieval to early Tudor	Removed (in curation)	NO
247	277000	35000	*de Boot*	Armed Cargo Vessel Cargo East Indiaman	1733	08/11/1738	Hanoverian	Unknown	YES
249	282500	76500	Logboat: Bovey Heathfield	Logboat	43	410	Roman	Unknown	NO
250	267400	41700	Logboat: Thurlestone Sands	Logboat	-500000	-55	Early Prehistoric Late Prehistoric	Removed (Unknown)	NO
251	283200	76100	Logboat: Bovey Tracey	Logboat	-500000	42	Early Prehistoric Late Prehistoric	Removed (Unknown)	NO
252	212000	145000	*Iona*	Craft	1300	1499	Medieval to early Tudor	Unknown	NO
253	243200	129700	Unknown Wreck: Westward Ho!	Armed Cargo Vessel Cargo East Indiaman	1770	1770	Hanoverian	Partially Buried	YES
254	243200	129700	Unknown Wreck: Northam	*Trow*	1750	1750	Hanoverian	Partially Buried	YES
255	325300	89900	Unknown Wreck: Axmouth-Seaton Ferry	Craft	1540	1900	Medieval to late Tudor Hanoverian	Partially Intact	YES

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
256	325270	90020	Axe Boat	Craft	1400	1640	Mid to late Tudor Stuart	Partially Intact	YES
257	365180	201480	Unknown Wreck: Lydney Docks	*Trow*	1700	1800	Stuart Hanoverian	Unknown	YES
259	472288	97646	Unknown Wreck: Hayling Island	Craft	43	409	Roman	Unknown	YES
260	450130	110510	*Holigost*	Warship *Hulk*	1066	1539	Medieval to early Tudor	Buried	NO
261	466266	87578	*Henry Addington*	Armed Cargo Vessel Cargo East Indiaman	1796	1798	Hanoverian	Unknown	YES
262	442564	109255	Unknown Wreck: Southampton	*Galley*	43	409	Roman	Unknown	NO
263	463485	104425	Gresham Wreck	Craft	1574	1578	Mid to late Tudor	Removed (in curation)	NO
264	445590	98230	Purbeck Marble Wreck	Craft	1066	1639	Medieval to early Tudor	Broken Up	NO
266	434500	130500	Logboat: Bossington	Logboat	-10000	42	Early Prehistoric Late Prehistoric	Removed (Unknown)	NO
267	444860	516340	Logboat: Thornby Canoe 1	Canoe/Logboat	-2400	-700	Late Prehistoric	Removed (in curation)	NO
270	515900	202300	Boat Burial: Old Parkbury	Logboat	-4500	-2501	Late Prehistoric	Removed (Unknown)	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
271	307800	496900	Findspot: Saltcoats Boat	Craft	-500000	1840	Unknown	Unknown	NO
274	355700	508000	Logboat: Shap Boat	Canoe/Logboat	1066	1539	Medieval to early Tudor	Removed (in curation)	NO
275	335000	435000	Logboat: Staining	Logboat	-10000	42	Early Prehistoric Late Prehistoric	Unknown	NO
276	361415	470639	Logboat: Wennington Hall	Logboat	-10000	42	Early Prehistoric Late Prehistoric	Removed (in curation)	NO
277	343960	415360	Logboat: Mere Sands Wood	Logboat	-4000	42	Late Prehistoric	Removed (Unknown)	NO
278	341000	416000	Logboat: Waring Ditch	Logboat	-4000	42	Late Prehistoric	Removed (Unknown)	NO
279	352500	429200	Logboat: Marsh Lane Quay	Logboat	-4000	42	Late Prehistoric	Unknown	NO
280	352500	429000	Logboat: Penwortham New Bridge	Logboat	-4000	42	Late Prehistoric	Unknown	NO
281	338700	445780	Logboat: Wellhouse Farm	Logboat	-4000	42	Late Prehistoric	Removed (Unknown)	NO
283	497347	371060	Findspot: Brayford Wharf East	Craft	1150	1250	Medieval to early Tudor	Unknown	NO
284	507700	369700	Logboat: Branston Fen	Logboat	-2200	-801	Late Prehistoric	Removed (Unknown)	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
285	509900	364800	Logboat: Nocton Delph (1)	Logboat	-2200	-801	Late Prehistoric	Removed (in curation)	NO
286	509900	364800	Logboat: Nocton Delph (2)	Logboat	-2200	-801	Late Prehistoric	Removed (in curation)	NO
287	488870	400900	Logboats: Scotter	Logboat	-2200	-801	Late Prehistoric	Unknown	NO
288	510370	370040	Logboat: Bardney Lock	Logboat	-2200	-801	Late Prehistoric	Unknown	NO
290	509750	371570	Logboat: Short Ferry Bridge	Logboat	-2200	-801	Late Prehistoric	Destroyed	NO
291	510300	370900	Logboat: Branston Island	Logboat	-2200	-801	Late Prehistoric	Removed (Unknown)	NO
292	501100	370800	Logboat: River Witham	Canoe/Logboat	-2200	-801	Late Prehistoric	Unknown	NO
293	515900	364800	Logboat: Stixwould	Logboat	1066	1539	Medieval to early Tudor	Unknown	NO
294	519550	362550	Logboat: Kirkstead	Logboat	1066	1539	Medieval to early Tudor	Unknown	NO
295	482500	400800	Logboat: East Ferry	Logboat	-2200	-801	Late Prehistoric	Removed (Unknown)	NO
296	488940	234820	Findspot: Caldecotte Boat	Craft	1400	1699	Medieval to early Tudor Mid to late Tudor	Unknown	NO
297	527270	409940	Boat Burial: Grimsby	Logboat	-4000	-2351	Late Prehistoric	Removed (in curation)	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
303	452500	334500	Findspot: Attenborough Gravel Pit	Craft	-2300	-701	Late Prehistoric	Removed (Unknown)	NO
307	345200	141700	Logboat: Meare	Logboat	-500000	1840	Unknown	Unknown	NO
308	443350	112950	Unknown Wreck: River Itchen	*Barge*/*Collier*/*Hulk*	1800	1850	Hanoverian	Partially Intact	YES
309	443431	110749	Unknown Wreck: Woolston Riverside	*Barge*/*Ketch*/*Hulk*	1800	1850	Hanoverian	Buried	YES
312	424000	323000	Logboat: Bond End	Logboat	-500000	1840	Unknown	Destroyed	NO
314	436700	568200	Findspot: Herd Sand	Passenger vessel Transport vessel	-54	409	Roman	Removed (Unknown)	NO
315	436900	568100	Unknown Wreck: Herd Sand	Craft	1700	1800	Hanoverian	Unknown	YES
317	395410	424580	Logboat: Lobbmill	Canoe/Logboat	-4000	409	Late Prehistoric Roman	Removed (in curation)	NO
318	628850	248750	Boat Burials: Sutton Hoo	Craft	601	700	Post-Roman	Destroyed	NO
319	651835	279295	Findspot: Steering Board	Craft	900	1199	Post-Roman Medieval to early Tudor	Removed (Unknown)	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
320	648068	298915	Findspot: Ashby Dell	Craft	410	1065	Post-Roman	Unknown	NO
321	639050	248550	Boat Burials: Burrow Hill	Craft	650	849	Post-Roman	Unknown	NO
322	526990	409520	Findspot: Riverhead	*Launch*	1066	1539	Medieval to early Tudor Mid to late Tudor	Unknown	NO
323	424174	637840	*George and Mary*	*Brig*	1823	04/02/1823	Hanoverian	Unknown	YES
324	647300	211830	*Albion*	Armed Cargo Vessel Cargo East Indiaman	1762	1765	Hanoverian	Dispersed	YES
325	668260	229621	*Prince Royal*	First rate Warship	1610	13/06/1666	Stuart	Unknown	YES
327	95497	13568	Findspot: *Forester*	*Brig*	1832	13/02/1833	Hanoverian	Removed (Unknown)	NO
328	543731	412492	*Bremen Packet*	Cargo Vessel Packet	1808	28/03/1808	Hanoverian	Unknown	YES
329	542046	411824	*Prosperity*	Cargo Vessel	1808	23/03/1808	Hanoverian	Unknown	YES
330	541947	411803	*Aurora*	Craft	1808	28/03/1808	Hanoverian	Unknown	YES
331	177290	16020	*Dispatch*	Passenger Vessel Transport vessel Troopship	1809	22/01/1809	Hanoverian	Unknown	YES
332	428920	84810	*Dream*	*Schooner / yatch*	1837	1850	Hanoverian	Broken up	NO
333	182232	33732	*Queen*	Passenger vessel Transport vessel Troopship	1814	14/01/1814	Hanoverian	Removed (in curation)	YES

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
334	569842	103209	Designated Wreck: Norman's Bay	Warship	1667	1703	Stuart	Partially Buried	NO
335	89708	9209	*Padstow*	*Brig* Cargo vessel	1804	24/12/1804	Hanoverian	Partially Intact	YES
336	164599	23350	Designated Wreck: Loe Bar	Armed Cargo Vessel Cargo East Indiaman	1600	1684	Stuart	Poor	NO
337	92022	13263	Innisidgen	Craft	1600	1810	Stuart	Poor	NO
338	515886	475707	HMS *Nautilus*	Sixth rate Warship *Sloop*	1784	1799	Hanoverian	Unknown	YES
339	513608	481113	Spittals Wreck	Cargo vessel	1780	1850	Hanoverian	Partially Intact	NO
340	443079	329205	Logboat: Aston-upon-Trent	Logboat	-1600	-1001	Late Prehistoric	Removed (in curation)	NO
341	442400	328600	Logboat: Shardlow Quarry	Logboat	-2350	-701	Late Prehistoric	Buried	NO
342	450980	331950	Findspot: Attenborough Quarry	Craft	1320	1340	Medieval to early Tudor	Removed (Unknown)	NO
343	543450	179250	The Woolwich Ship	Craft	1450	1602	Medieval to early Tudor	Unknown	YES
344	649366	159406	Unknown Wreck: GAD 58	Craft	1600	1850	Stuart Hanoverian	Broken up	YES

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
345	636372	160557	Unknown Wreck: GAD 108	Cargo vessel	1400	1800	Medieval to late Tudor Stuart Hanoverian	Partially Intact	YES
346	323000	390000	Unknown Wreck: Meols 'Viking' Ship	Cargo vessel	900	1600	Post-Roman Medieval to late Tudor	Buried	YES
347	523600	296800	Logboats: Must Farm	Logboat	1300	400	Late Prehistoric	Unknown	NO
348	505500	371600	Logboat: Fiskerton	Logboat	-800	42	Late Prehistoric	Removed (in curation)	NO
349	614800	212800	Findspot: Jaywick	Craft	-10000	-4001	Early Prehistoric Late Prehistoric	Removed (Unknown)	NO
350	615300	212900	Findspot: Jaywick	Craft	-4000	-2351	Late Prehistoric	Removed (in curation)	NO
351	534950	187500	Logboat: Clapton	Logboat	950	1050	Post-Roman	Unknown	NO
352	653000	281000	Logboat: Covehithe	Logboat	775	892	Post-Roman	Removed (Unknown)	NO
353	454013	527581	Unknown Wreck: North Gare	CRAFT	1700	1900	Hanoverian	Buried	YES
354	576170	169500	Findspot: HMS *Namur*	Second rate Warship	1756	1833	Hanoverian	Removed (in curation)	NO
355	572859	167064	Historic Vessel: Light vessel 16 Inner Dowsing	Craft Lightship	1840	2012	Hanoverian	Extant	NO
356	451153	533079		Warship *Frigate*	1816	2012	Hanoverian	Extant	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
			Historic Vessel: HMS *Trincomalee*						
358	462932	100550	Historic Vessel: HMS *Victory*	First rate Warship	1765	2012	Hanoverian	Extant	NO
359	538716	177690	Historic Vessel: Prince Frederick's Barge	Passenger vessel *Barge*	1732	2012	Hanoverian	Extant	NO
360	460760	525147	Historic Vessel: *Zetland*	Lifeboat	1802	2012	Hanoverian	Extant	NO
361	437075	567539	Historic Vessel: *Tyne*	Lifeboat	1833	2012	Hanoverian	Extant	NO
363	442611	264699	Historic Vessel: *Laplander*	Iceboat	1830	2012	Hanoverian	Extant	NO
364			Historic Vessel: *Katie*	*Smack*	1830	2012	Hanoverian	Extant	NO
365	601032	213004	Historic Vessel: *Boadicea* CK 213	Fishing vessel *Smack*	1808	2012	Hanoverian	Extant	NO
366	476703	182064	Historic Vessel: *Royal Oak*	Leisure Craft *Gig*	1812	2012	Hanoverian	Extant	NO
367	476703	182064	Historic Vessel: Oxford Boat	Leisure Craft Racing Craft	1812	1012	Hanoverian	Extant	NO
368	538716	177690		Passenger vessel *Barge*	1689	2012	Stuart	Extant	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
			Historic Vessel: Queen Mary's Shallop	*Shallop*					
369	462932	100550	Historic Vessel: *Mary Rose*	Warship *Carrack*	1511	19/07/1545	Medieval to early Tudor	Extant	NO
370	605148	214167	Historic Vessel: *William and Emily*	Fishing vessel *Smack*	1830	2012	Hanoverian	Extant	NO
371	91003	10989	Historic Vessel: *Bonnet*	Pilot vessel *Gig*	1830	2012	Hanoverian	Extant	NO
372	462932	100550	Historic Vessel: Charles II's State Barge	Passenger vessel *Barge* *Shallop*	1685	2012	Stuart	Extant	NO
373	180816	61848	Historic Vessel: *Dove*	*Gig*	1820	2012	Hanoverian	Extant	NO
375	417609	634825	Historic Vessel: *Grace Darling*	*Coble*	1830	2012	Hanoverian	Extant	NO
376	334120	91450	*Heroine*	Armed Cargo Vessel Cargo Emigrante ship *Barque*	1838	27/12/1852	Hanoverian	Partially Intact	YES
377	151633	30816	Historic Vessel: Lord St.Levan's Old Ceremonial Barge	*Barge*	1740	2012	Hanoverian	Extant	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
378	340369	497798	Historic Vessel: *Margaret*	*Yatch*	1760	2012	Hanoverian	Extant	NO
379	637248	324721	Historic Vessel: *Maria*	Leisure Craft Racing craft	1827	2012	Hanoverian	Extant	NO
380	405396	86123	Unknown Wreck: Antler Wreck	Cargo Vessel	1700	1800	Hanoverian	Poor	NO
381	509677	428790	Historic Vessel: West Greenland Kayak	Canoe	1800	1900	Hanoverian	Extant	NO
382	509677	428790	Historic Vessel: Eastern Canada kayak	Canoe	1830	2012	Hanoverian	Extant	NO
383	509677	428790	Historic Vessel: West Greenland Kayak	Canoe	1833	2012	Hanoverian	Extant	NO
384	151633	30816	Historic Vessel: *Newquay*	*Gig*	1812	2012	Hanoverian	Extant	NO
386	91003	10989	Historic Vessel: *Slippen*	*Gig*	1830	2012	Hanoverian	Extant	NO
387	151633	30816	Historic Vessel: *Treffry*	Pilot vessel *Gig*	1838	2012	Hanoverian	Extant	NO
388	583417	94747	*Thomas Lawrence*	Passenger vessel *Schooner*	1838	1862	Hanoverian	Buried	NO
389	501740	516522	*Black Prince*	Passenger vessel *Brig*	1838	1890	Hanoverian	Broken up	YES

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
390	320250	391800	*Robert Seymour*	*Schoone*	1839	15/05/1881	Hanoverian	Unknown	YES
391	549180	181250	HMS *Cornwall*	Third rate Training ship Guard ship	1815	1940	Hanoverian	Removed (Unknown)	NO
393	511560	428610	*Fanny*	Cargo vessel *Sloop*	1834	15/10/1877	Hanoverian	Unknown	NO
394	531230	413350	*Triton*	Cargo vessel *Schooner*	1822	25/09/1851	Hanoverian	Unknown	NO
396	324440	153490	*James and Sarah*	Cargo vessel *Ketch*	1830	15/09/1880	Hanoverian	Unknown	YES
398	133969	30985	*Devon*	Cargo vessel *Sloop*	1833	23/10/1868	Hanoverian	Unknown	YES
399	83710	6140	*Thames*	Packet Paddle Steamer	1827	04/01/1841	Hanoverian	Broken up	YES
400	82660	7380	*Douro*	Cargo vessel Slave ship *Snow*	1839	28/01/1843	Hanoverian	Broken up	YES
401	181160	20180	*John*	Armed Cargo Vessel Cargo Emigrante ship *Barque*	1810	03/05/1855	Hanoverian	Broken up	YES

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
402	334488	386323	HMS *Clarence*	Admiralty vessel *Hulk* Reformatory ship Training ship	1833	26/07/1899	Hanoverian	Dispersed	NO
403	170792	11522	*Robert*	*Schooner*	1840	29/07/1888	Hanoverian	Poor	NO
405	499130	425240	Findspot: Ferriby	Craft	-1200	-700	Late Prehistoric	Removed (in curation)	NO
406	541750	416650	Findspot: Kilnsea	Craft	-1870	-1670	Late Prehistoric	Removed (Unknown)	NO
407	499290	407610	Findspot: Brigg Raft	Craft	-2600	-700	Late Prehistoric	Removed (in curation)	NO
408	482200	432600	Logboat: Hasholme	Logboat	-277	43	Late Prehistoric	Removed (in curation)	NO
409	526000	297000	Logboat: Whittlesey	Logboat	-4000	-700	Late Prehistoric	Removed (Unknown)	NO
410	522200	296200	Logboats: River Nene	Logboat	-500000	1840	Unknown	Buried	NO
411	535500	190660	Boat Burial: Lockwood Reservoir	Craft	867	899	Post-Roman	Removed (in curation)	NO
412	586510	127580	Findspot: Maytham Wharf	*Cog*	1500	1623	Mid to late Tudor	Removed (Unknown)	NO
413	640300	259200	Boat Burial: Snape	Craft	550	650	Post-Roman	Removed (in curation)	NO
414	606600	163900	Findspot: Graveney	Cargo vessel	895	895	Post-Roman	Removed (in curation)	NO

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
415	577700	185900	Findspot: Hastens Camp	Craft	893	893	Post-Roman	Removed (Unknown)	NO
416	635300	324400	Logboat: River Ant	Logboat	410	1065	Post-Roman	Removed (in curation)	NO
417	82840	8940	Unknown Wreck: Western Rocks	Fire ship Warship	1694	22/10/1707	Stuart Hanoverian	Unknown	YES
418	589940	175010	HMS *Lenox*	Third rate Warship	1678	01/04/1756	Stuart Hanoverian	Unknown	NO
419	639791	153779	Designated Wreck: GAD 8	Armed Cargo vessel	1650	1750	Stuart Hanoverian	Partially Buried	NO
420	649019	159378	Unknown Wreck: GAD 9	Armed Cargo vessel	1600	1900	Stuart Hanoverian	Partially Buried	YES
421	636919	157690	Unknown Wreck: GAD 10	Armed Cargo vessel	1700	1900	Hanoverian	Partially Intact	YES
422	649331	159318	Unknown Wreck: GAD 12	Armed Cargo vessel	1540	1900	Mid to late Tudor Stuart Hanoverian	Broken up	YES
423	649258	159274	Unknown Wreck: GAD 13	Armed Cargo vessel	1540	1900	Mid to late Tudor Stuart Hanoverian	Unknown	YES
424	649153	161004	Unknown Wreck: GAD 14	Armed Cargo vessel	1540	1900	Mid to late Tudor Stuart Hanoverian	Broken up	YES
425	649160	159732	Unknown Wreck: GAD 16	Armed Cargo vessel	1500	1600	Medieval and early Tudor to late Tudor	Unknown	YES

WA ID	Easting	Northing	Name	Craft Type	Min Date	Max Date	ESB Period	Survival	Selected
426	550400	179000	Findspot: Bronze Age Way	Craft	1540	1900	Mid to late Tudor Stuart Hanoverian	Removed (Unknown)	NO
427	552940	178010	Unknown Wreck: Bexley, The Saltings	*Barge/Hulk/Thames Sailing Barge*	1800	1900	Hanoverian	Mainly Intact	YES
428	354180	378440	*Daresbury*	*Barge/Hulk/Mersey Flat*	1772	1957	Hanoverian	Mainly Intact	YES
429	545000	309000	Logboats: Wisbech	Logboat	-500000	42	Early Prehistoric	Unknown	NO
430	549200	265200	Logboat: Waterbeach	Canoe Logboat	-500000	42	Early Prehistoric to Late Prehistoric	Unknown	NO
431	513000	169000	Logboat: West Molesey	Logboat	-500000	42	Early Prehistoric to Late Prehistoric	Removed (in curation)	NO
432	515400	168400	Logboat: East Molesey	Logboat	-500000	42	Early Prehistoric to Late Prehistoric	Unknown	NO
433	509900	167100	Logboat: Walton	Logboat	405	530	Post-Roman	Removed (in curation)	NO
434	83900	5300	*Royal Oak*	Armed Cargo Vessel Cargo East Indiaman	1663	15/02/1665	Stuart	Broken up	YES
435	334055	389838	Historic Vessel: The Green Boat	Leisure craft	1775	2012	Hanoverian	Extant	NO
436	434490	116230	Findspot: Testwood Lakes	Craft	-1500	-1500	Late Prehistoric	Removed (in curation)	NO

Table 5. The list is based on the WA list of wrecks ranging from pre-history to 1840 (Wessex Archaeology 2013) **and modified by the author of the thesis.**

1.6.2 Maps

1.6.2.1 EBS (prehistory-1840) in the UK

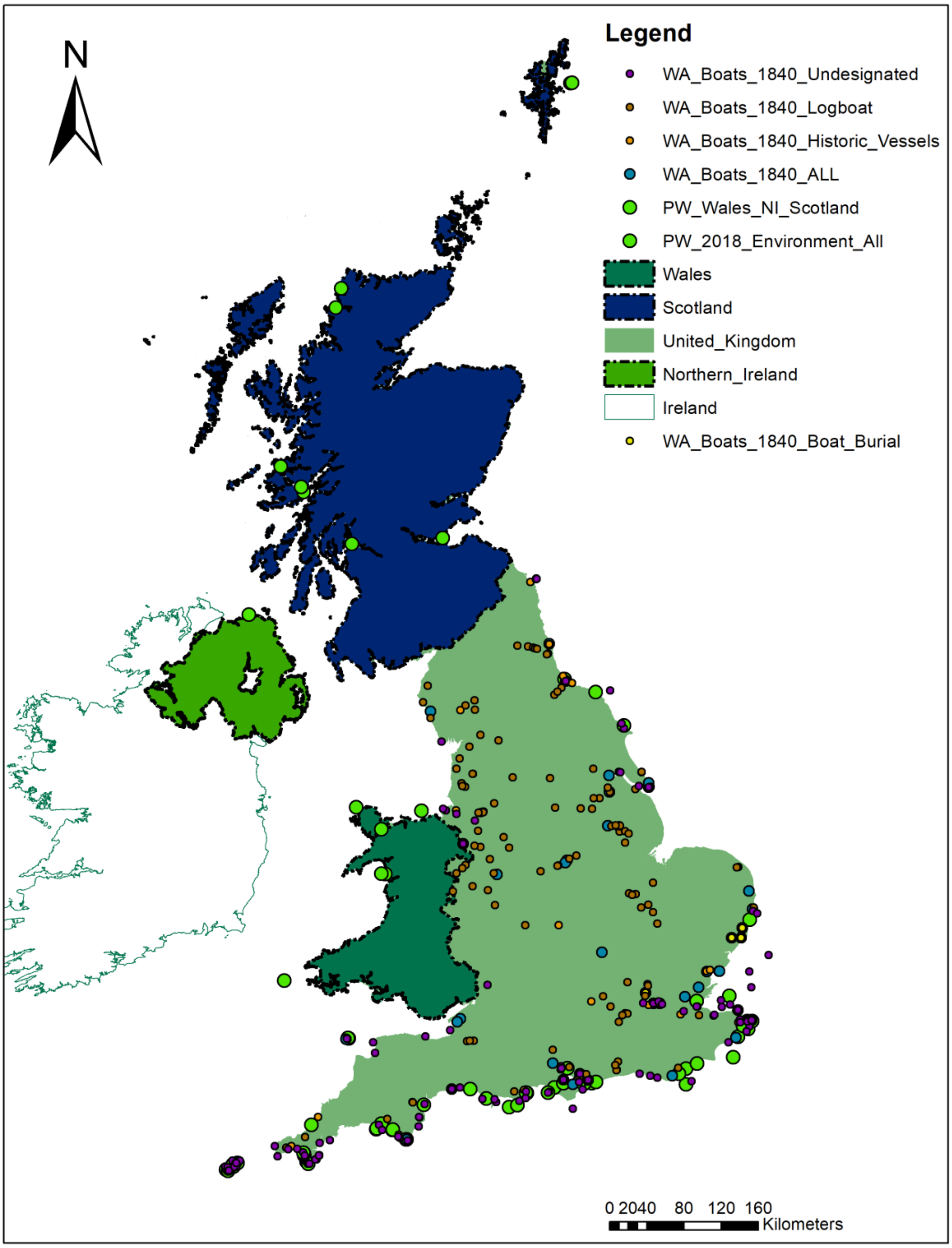


Figure 25. The map shows all the Protected Wrecks of the UK (Geography & Technology 2018; HE 2018a; Historic Environment Scotland 2016; Open Data NI 2018) **and ESB from prehistory to 1840 identified by WA** (Wessex Archaeology 2013)**. The coastline and boundaries are from EEA and NGA** (EEA 2018; National Geospatial-Intelligence Agency 2018)**. The author of this thesis created an image in ArcMap 10.5®.**

North of England

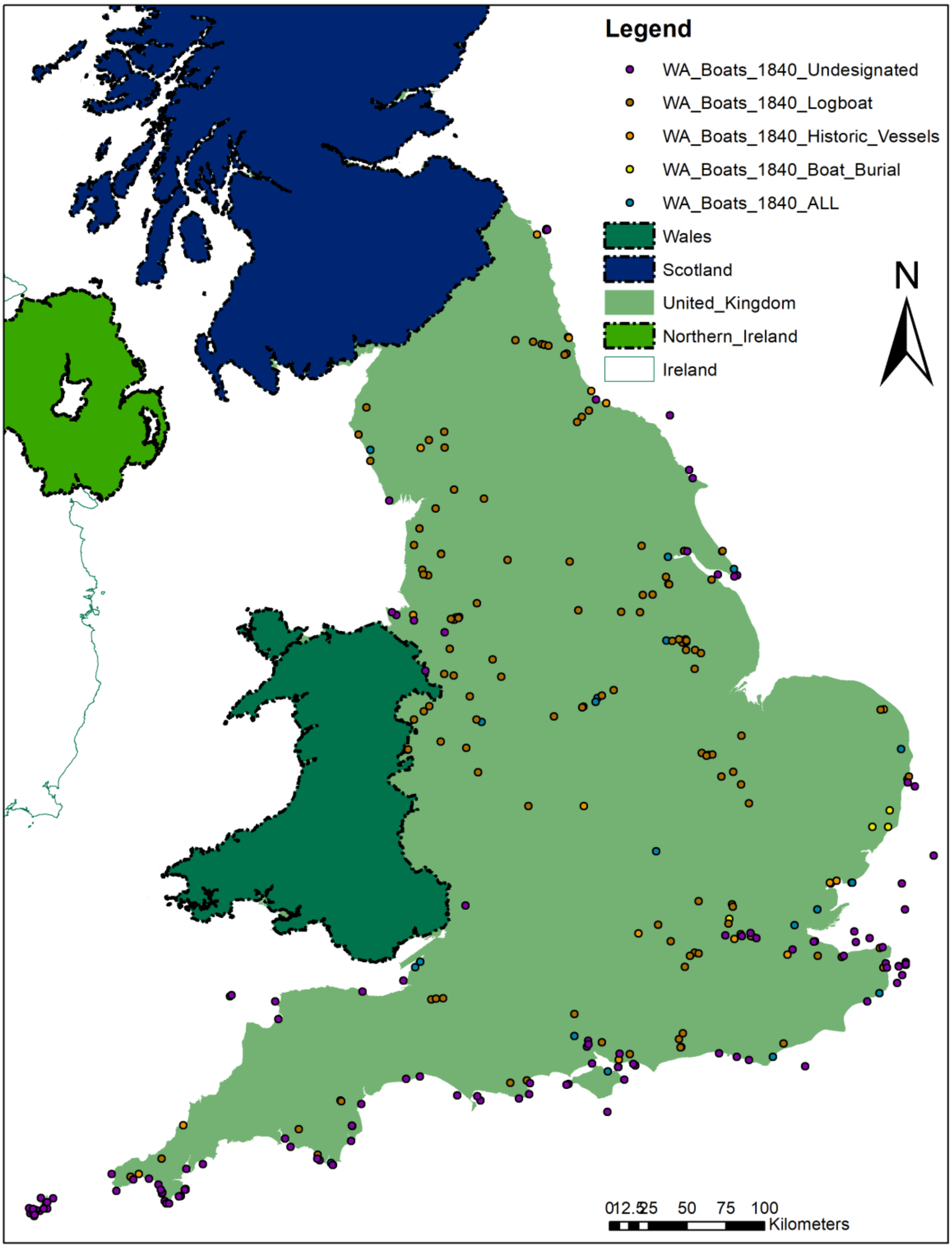


Figure 26. The map shows a close up of the North of England, with all the ESB (prehistory to 1840) identified by WA (Wessex Archaeology 2013) **and displayed by the author of this thesis. The boundaries are from EEA, and NGA** (EEA 2018; National Geospatial-Intelligence Agency 2018)**. The author of this thesis created an image in ArcMap 10.5®.**

Southeast England

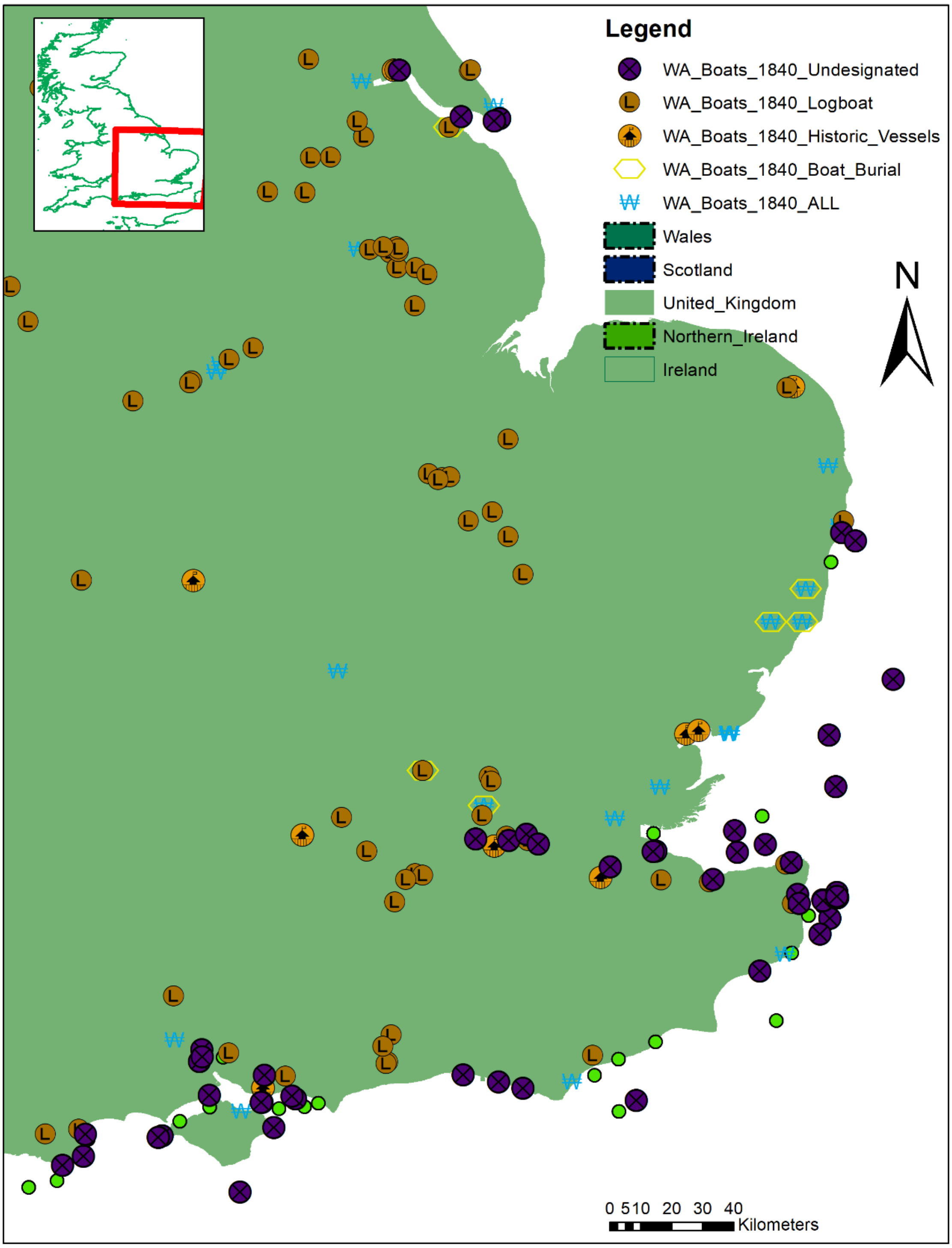


Figure 27. The map shows a close up of the Southeast of England, with all the ESB (prehistory to 1840) identified by WA (Wessex Archaeology 2013). The boundaries are from EEA, and NGA (EEA 2018; National Geospatial-Intelligence Agency 2018). The author of this thesis created an image in ArcMap 10.5®.

Southwest England

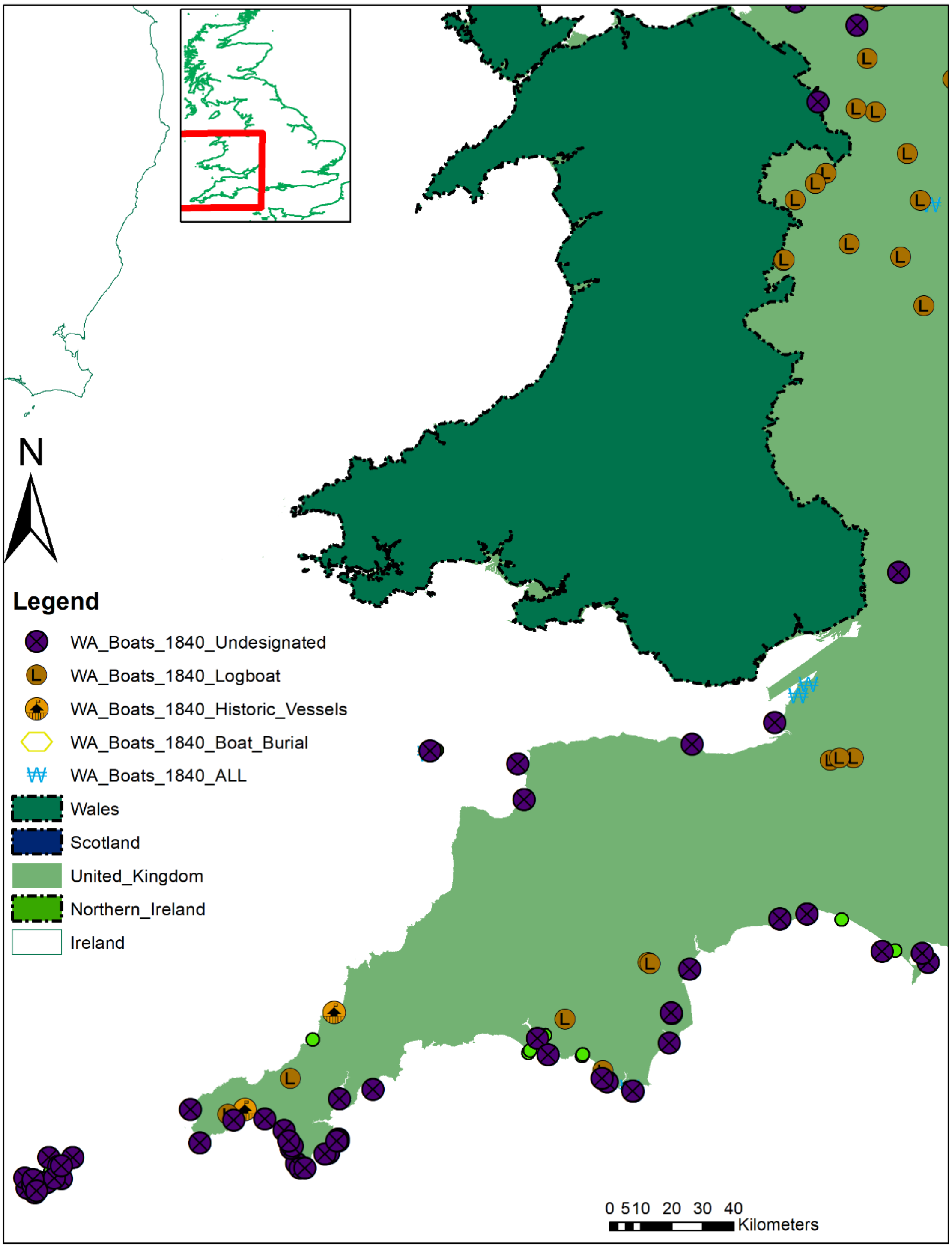


Figure 28. The map shows a close up of the Southwest of England, with all the ESB (prehistory to 1840) identified by WA (Wessex Archaeology 2013)**. The boundaries are from EEA, and NGA** (EEA 2018; National Geospatial-Intelligence Agency 2018)**. The author of this thesis created an image in ArcMap 10.5®.**

1.6.2.2 PW Ireland

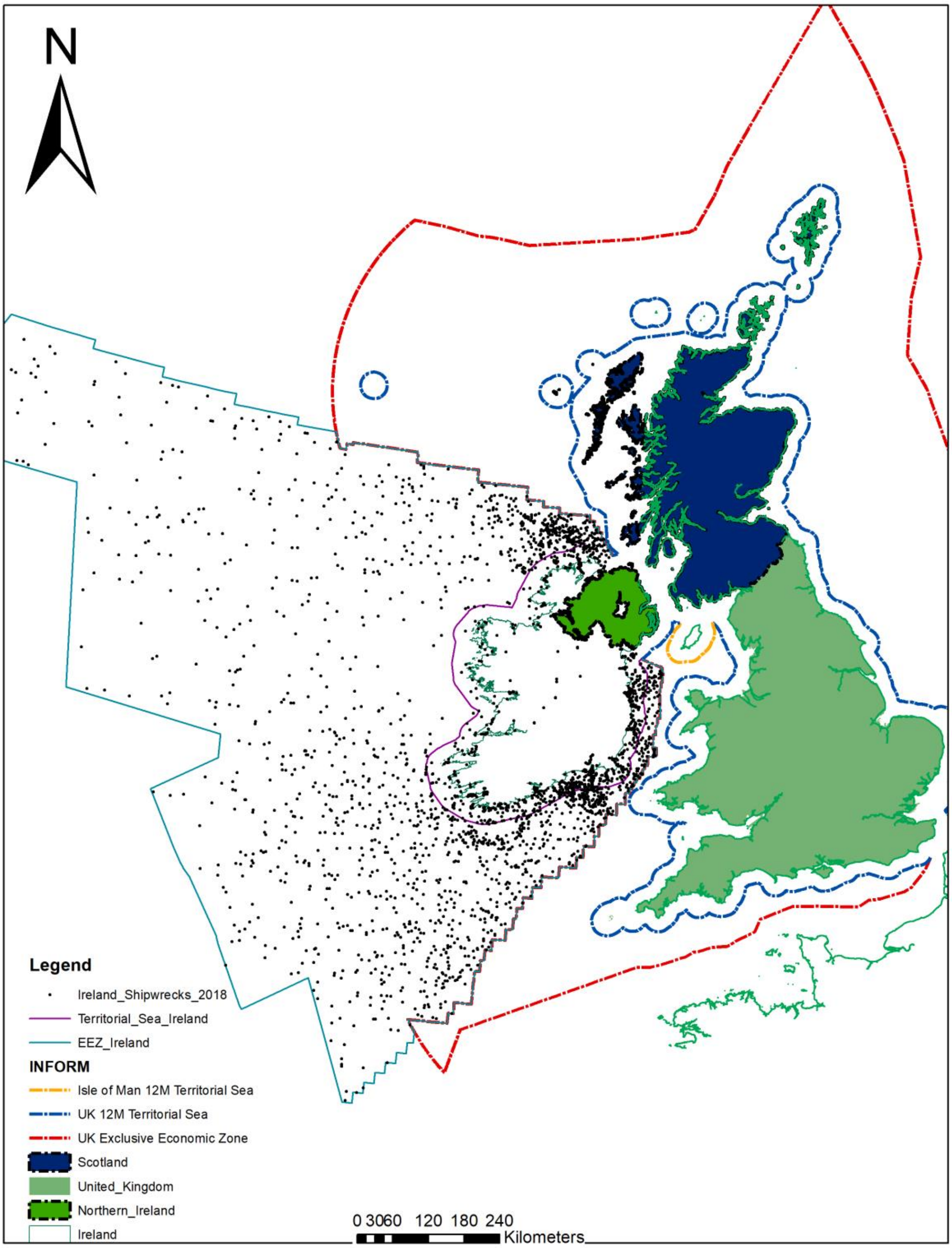


Figure 29. The map shows the Protected Wrecks in Ireland (National Monuments 2018) **within the EEZ and Territorial waters of Ireland** (Open Data Unit 2018)**. The coastline and boundaries** (EEA 2018; NCEI 2017) **the EEZ**

and territorial waters of the UK are from EEA (EEA 2018)**. The author of this thesis created an image in ArcMap 10.5®.**

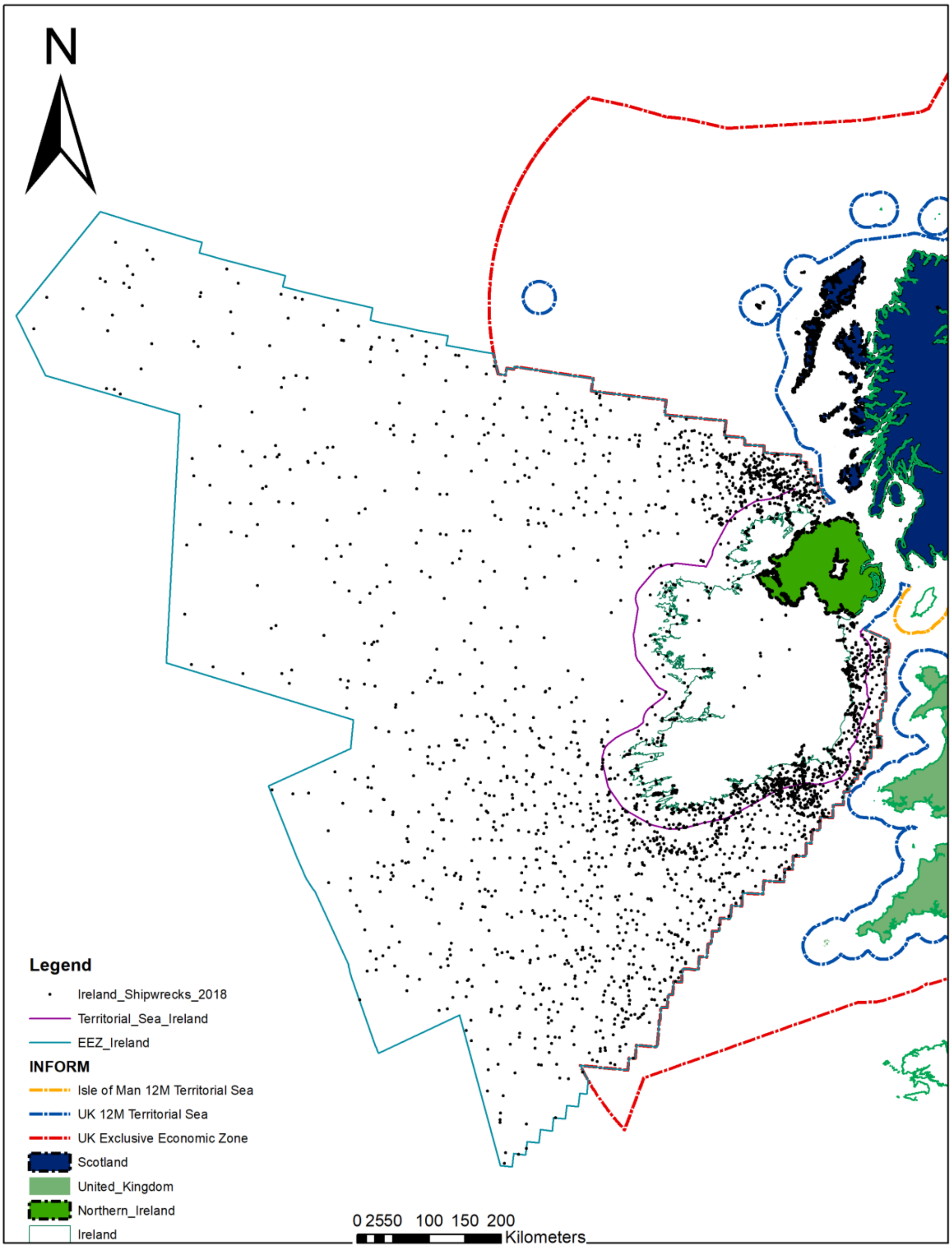


Figure 30. The map shows the Protected Wrecks in Ireland (National Monuments 2018) **within the EEZ and Territorial waters of Ireland** (Open Data Unit 2018)**. The coastline and boundaries** (EEA 2018; NCEI 2017) **the EEZ and territorial waters of the UK are from EEA** (EEA 2018)**. The author of this thesis created an image in ArcMap 10.5®.**

Appendix II. Notes on Case Studies (Chapters V, VI and VII)

A. *Hazardous* Prize 1699-1706 (Chapter V)

- Historical
- Geophysics
- Photogrammetry
- Field Work

2.A.1 Historical. *Hazardous* Prize 1699-1706

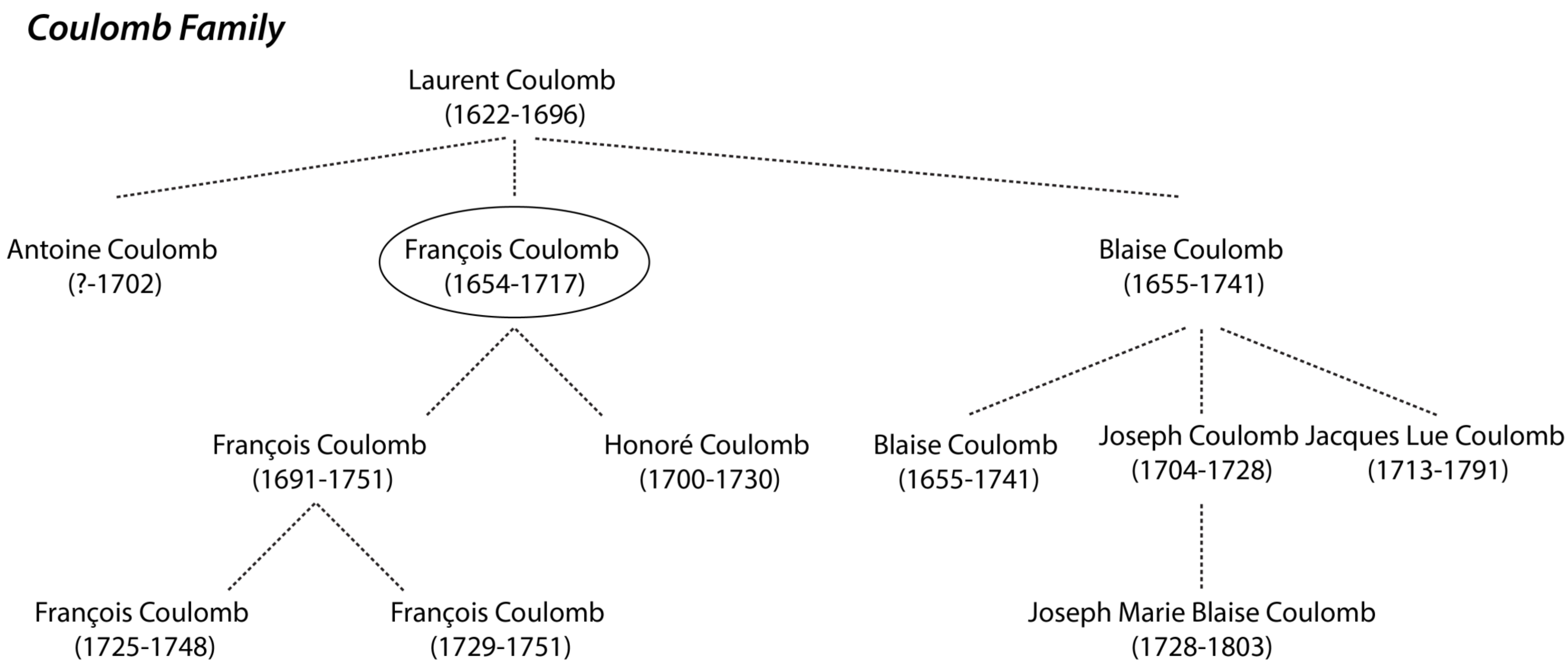


Figure 31. The image shows a family tree with dates of birth of the Coulomb family. The image clarifies shipbuilder's names that are related to the construction of certain vessels.

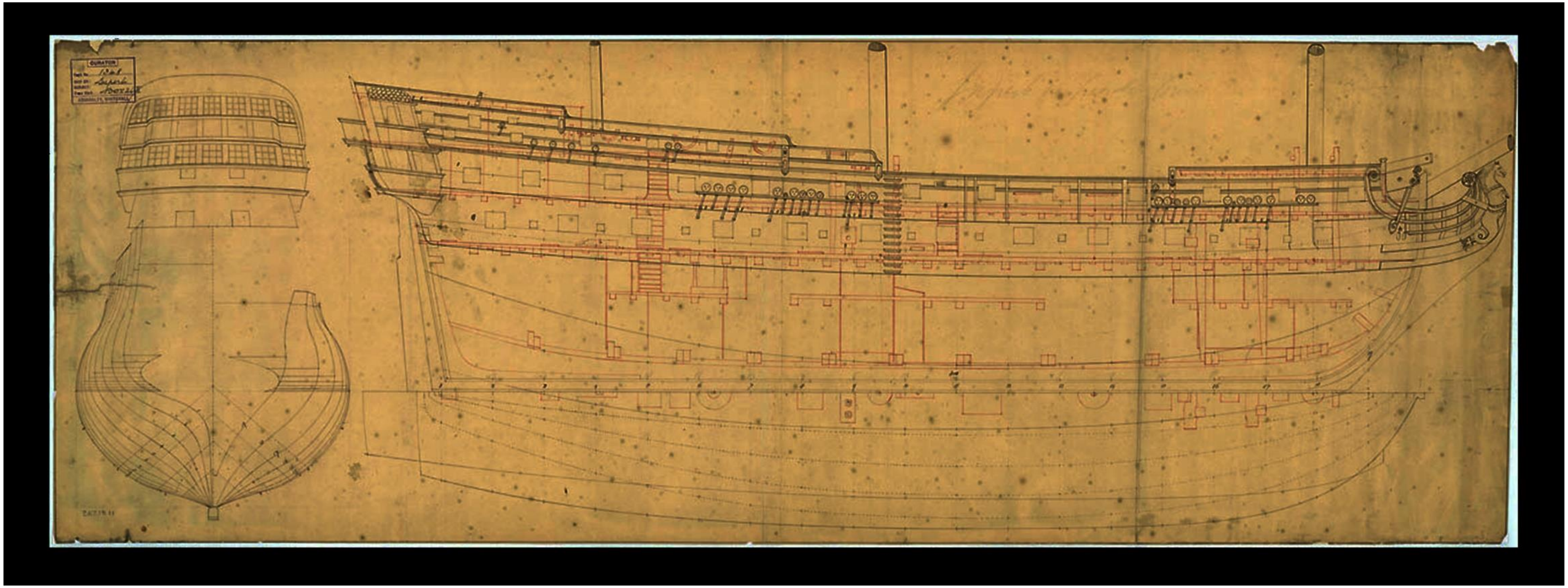


Figure 32. The figure shows the lones plan for *Le Superb*, captured by the British Navy in 1710. The original plan is held at the NNM (Uknown n.d.)**. The author of the thesis enhanced the image to make the lines stand out.**

Hazardous Prize 1706

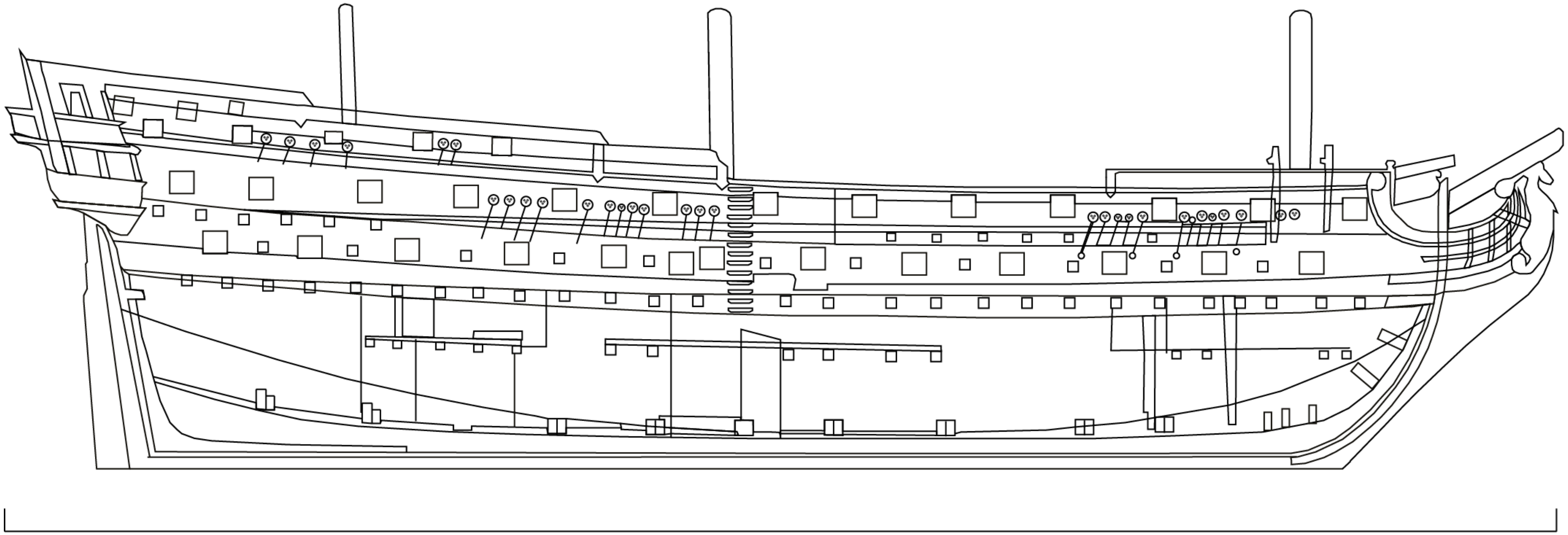


Figure 33. The figure shows the hypothetical lines plan of *Hazardous* 1703, based on the original lines of another French Fourth-rate, also captured by the British, *Le Superb* is shown in the previous figure.

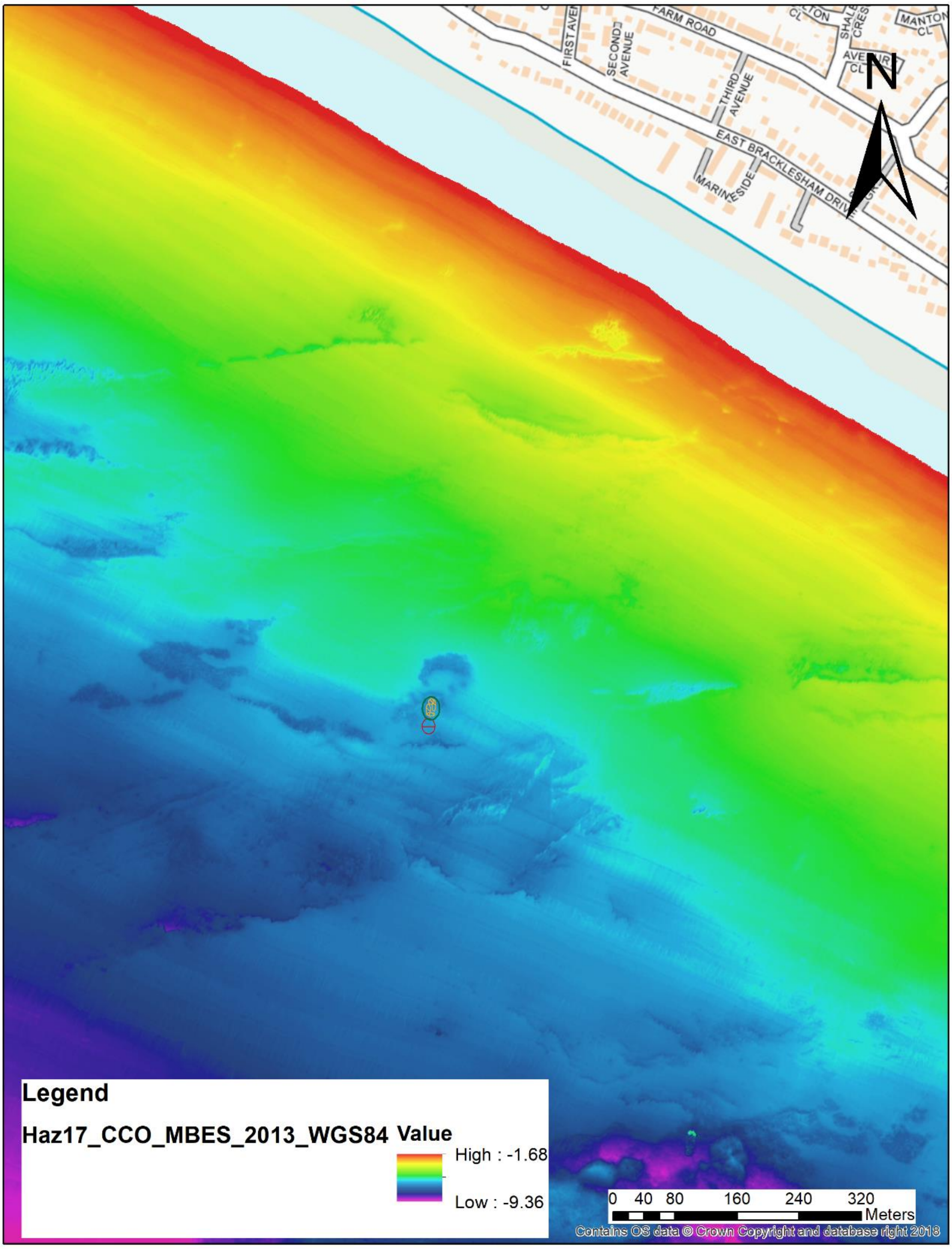


Figure 34. *Hazardous Prize* location showing the surrounding reefs on the MBES survey of Bracklesham Bay, done by the CCO (CCO 2018)**. The wreck location was converted from OSGB36 to WGS84 30N, with the original position from HE** (2018a) **The coastline shows ©Open Street Map 2010 based on ©Ordnance Survey 2010. The author of this thesis with Arc Map 10.5® created the map.**

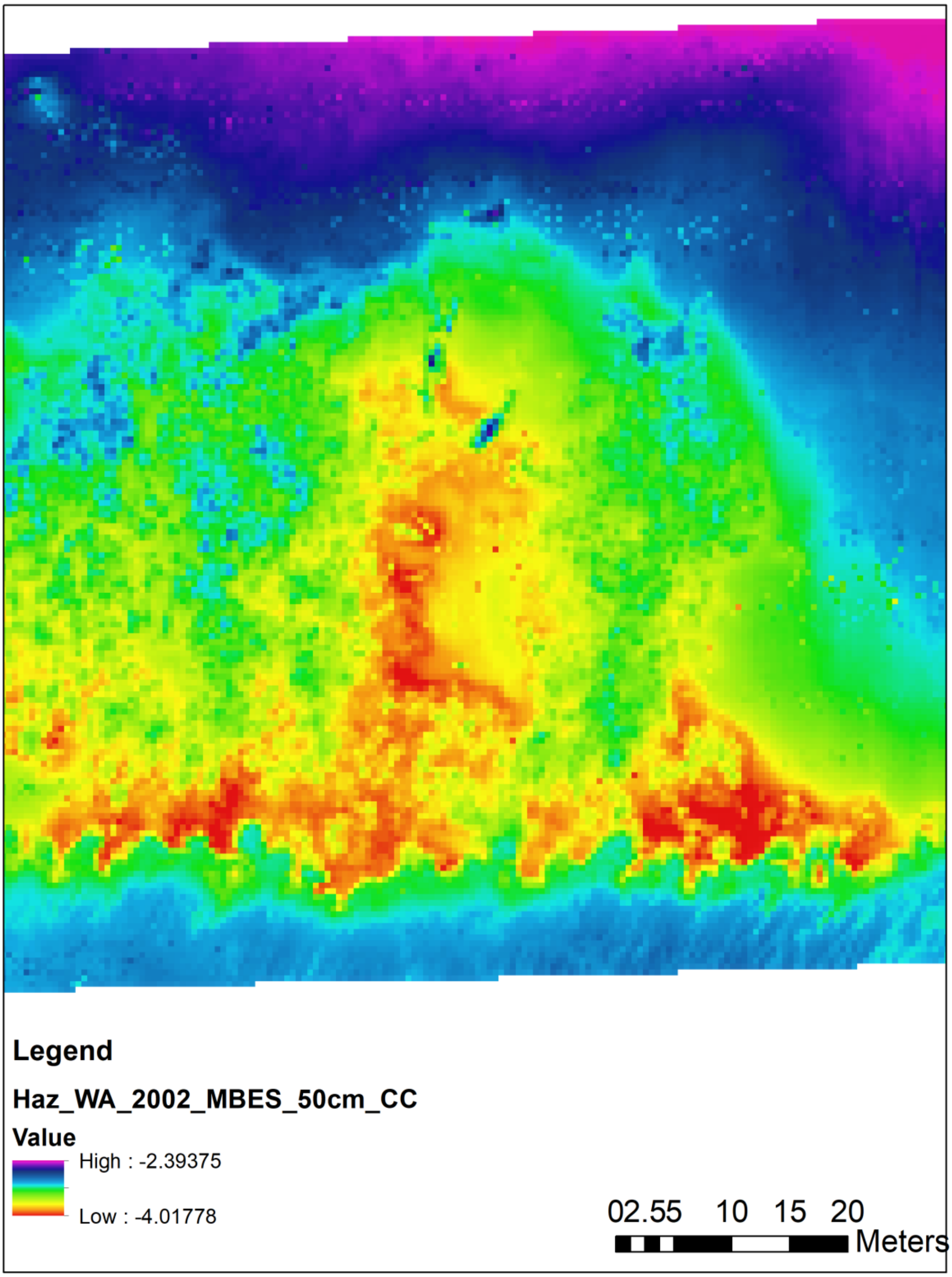


Figure 35. The figure shows a MBES survey at a 50 cm resolution, carried out by WA 2002. The author of this thesis created this map in ArcMap 10.5 ®.

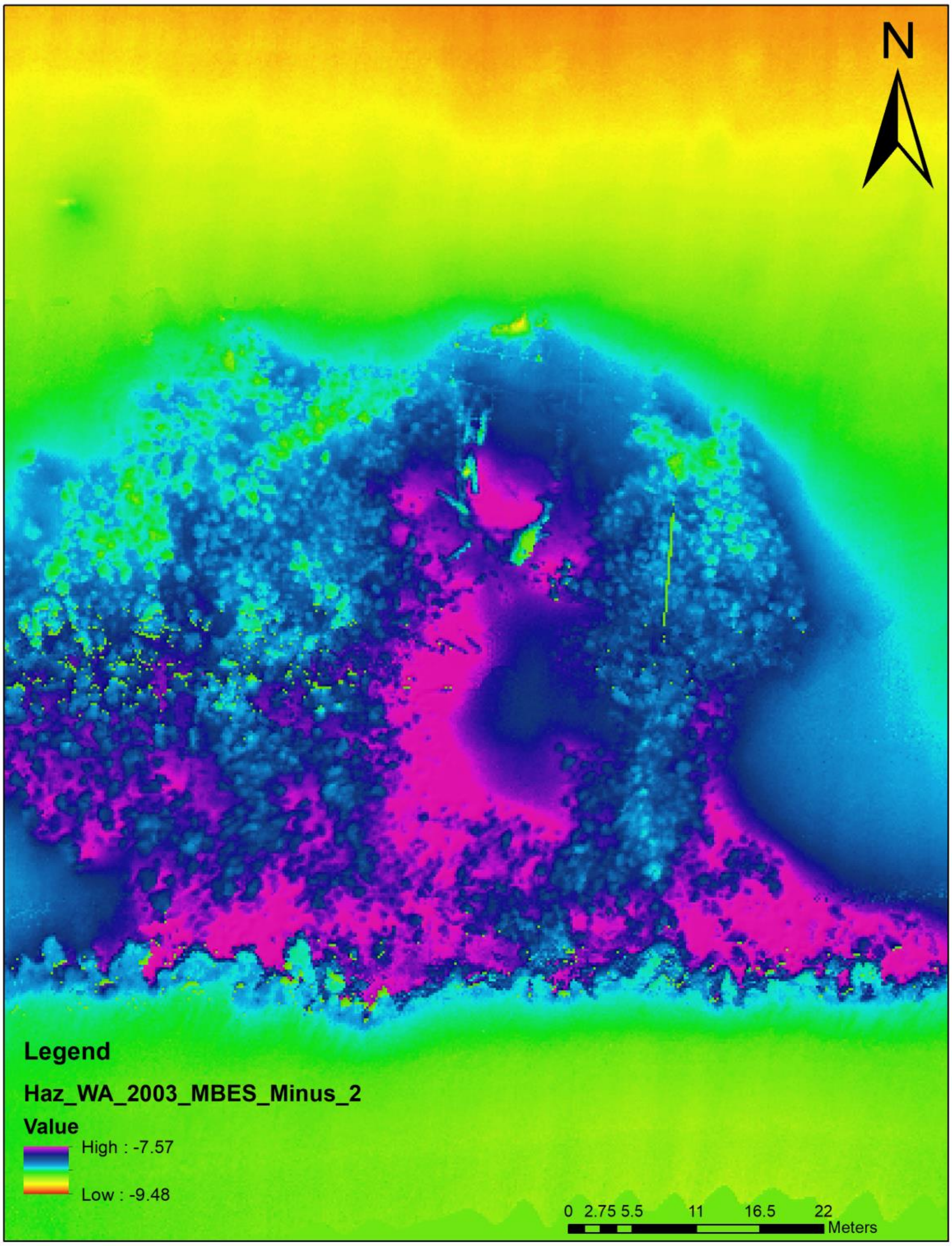


Figure 36. The figure shows a MBES survey at a 50 cm resolution, carried out by WA 2003. The author of this thesis created this map in ArcMap 10.5 ®.

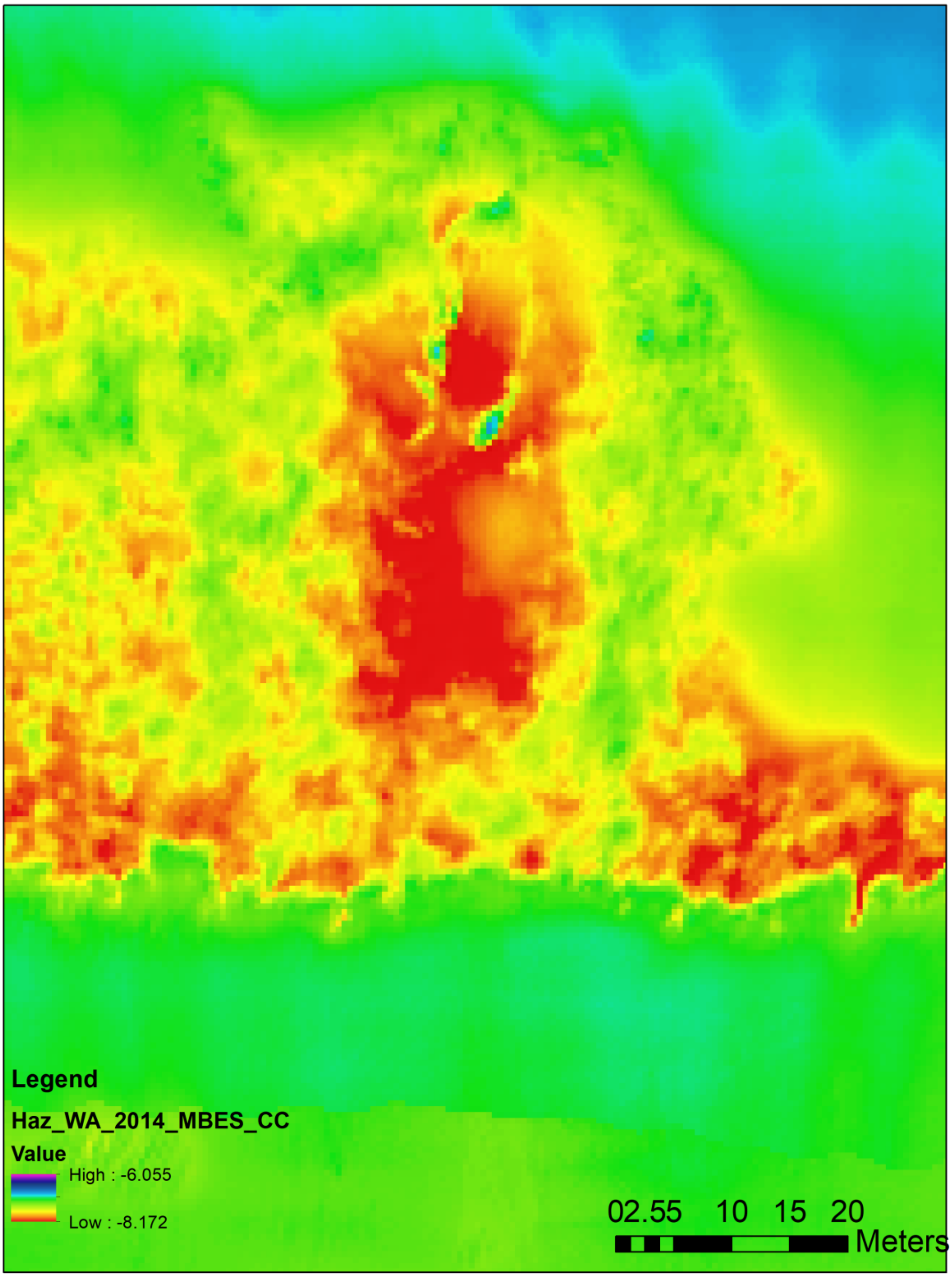


Figure 37. The figure shows a MBES survey at a 50 cm resolution, carried out by WA 2014. The author of this thesis created this map in ArcMap 10.5 ®.

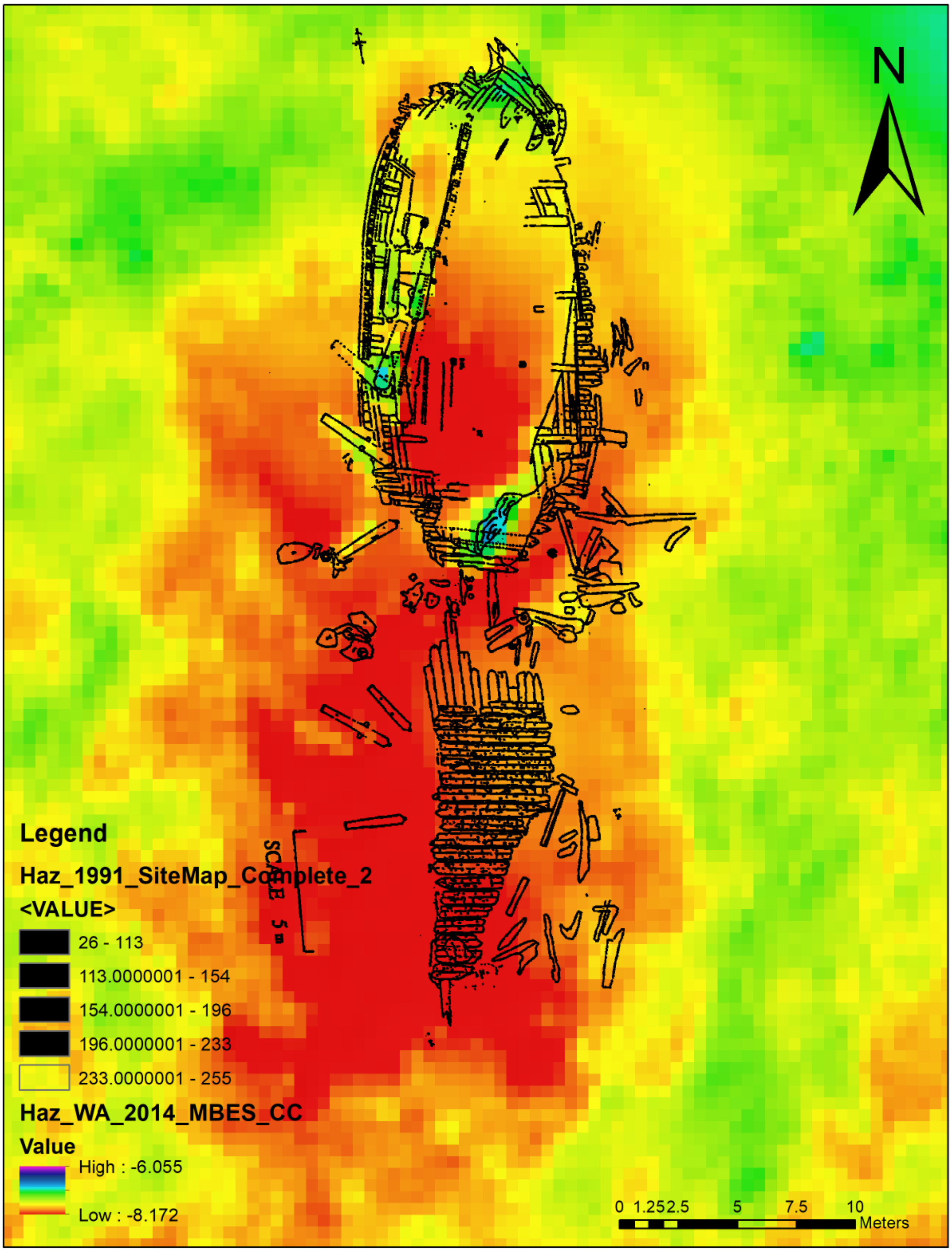


Figure 38. The figure shows a MBES survey at a 50 cm resolution, carried out by WA 2014 with an overlapping site plan by Owen (1991). The author of this thesis created this map in ArcMap 10.5 ®.

2.A.3 Photogrammetry. *Hazardous* Prize 1699-1706

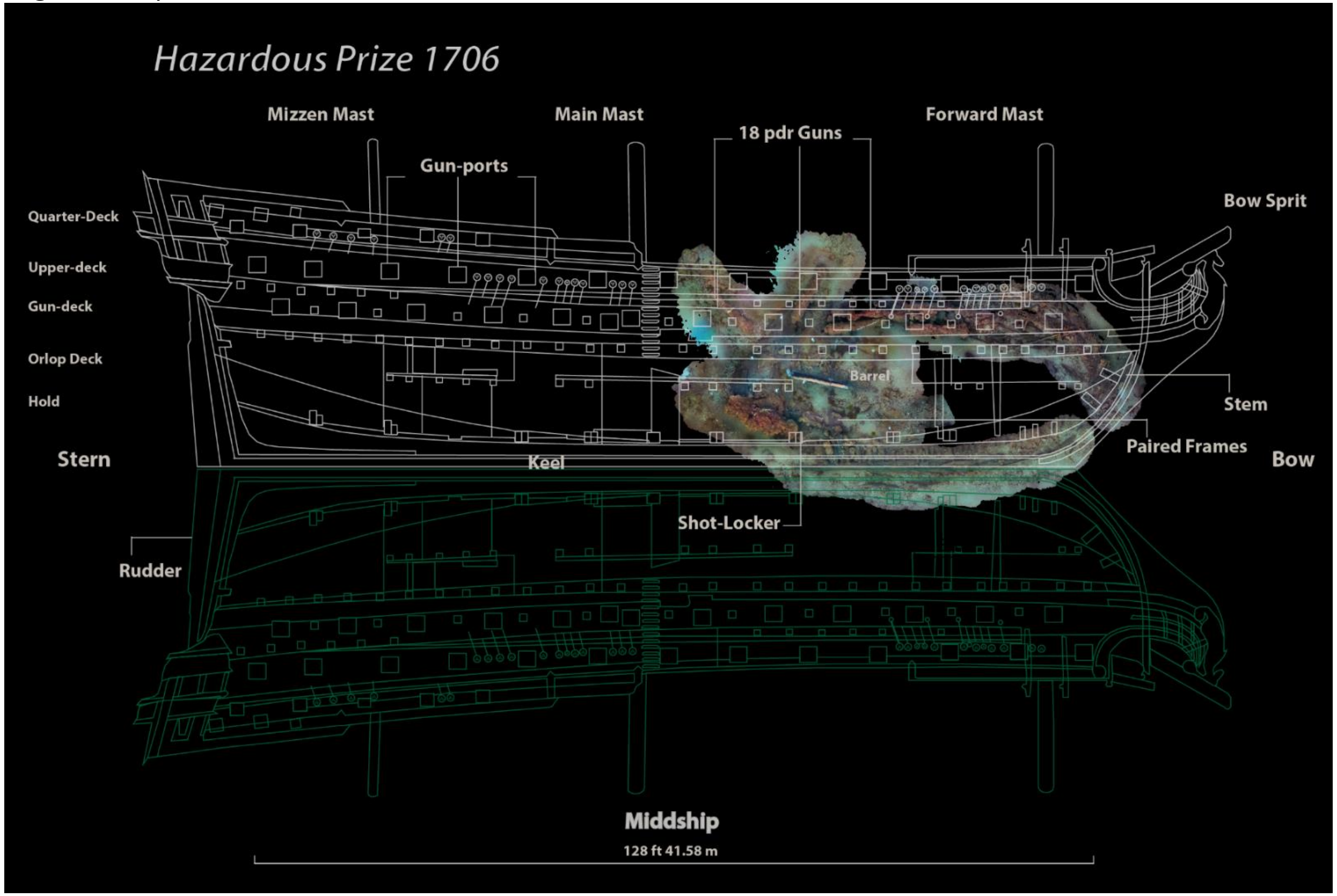


Figure 39. The image shows both port (white) and starboard (green) sides based on the *Hazardous* ship-lines. The orthophoto in the background shows the part of the wreck that was surveyed. The author of this thesis created the image.

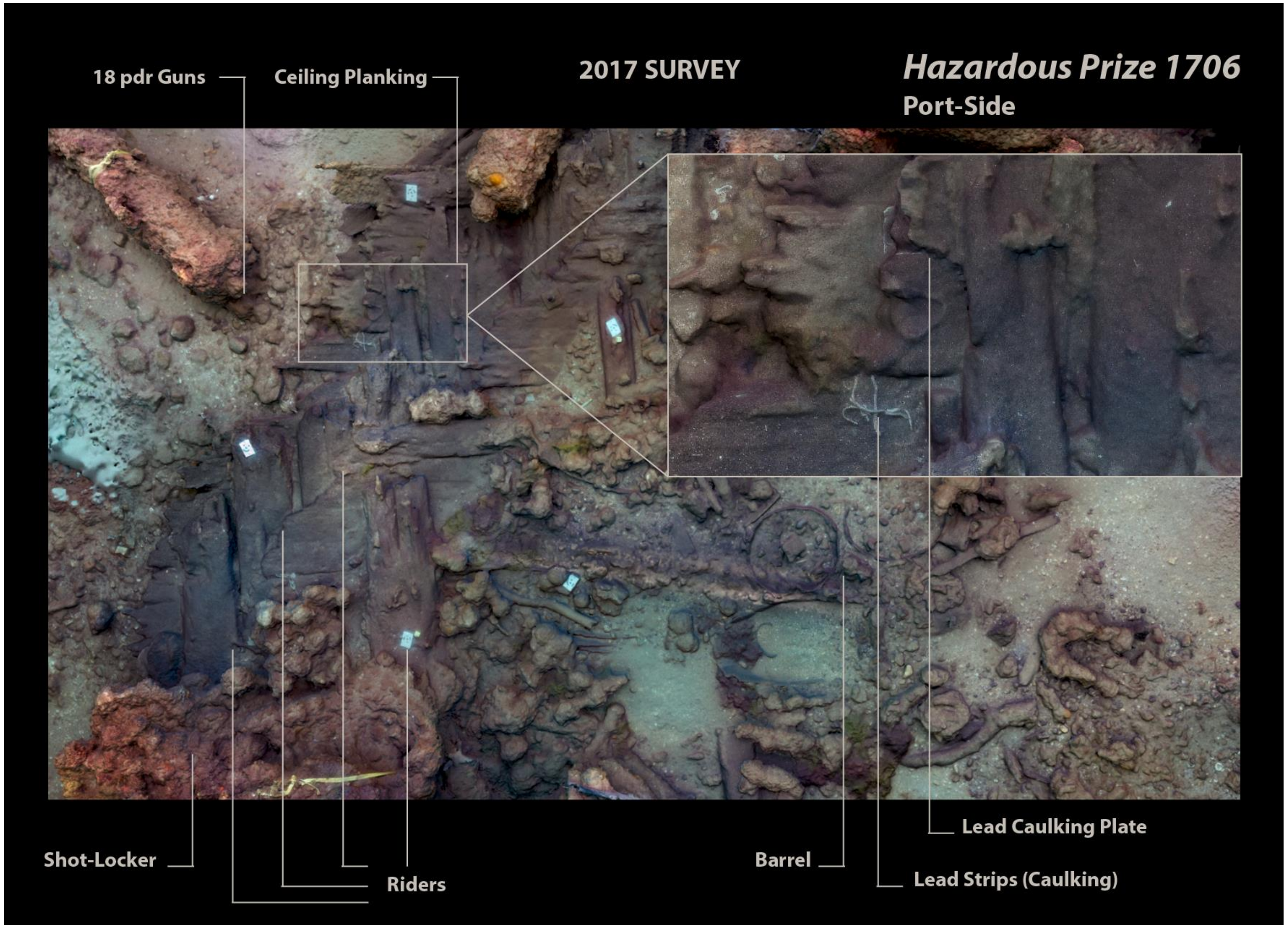


Figure 40. The author of this thesis did the photogrammetry survey and processed it on Agisoft Metashape Pro v1.5 ®. The image was rendered in 3dsMax®.

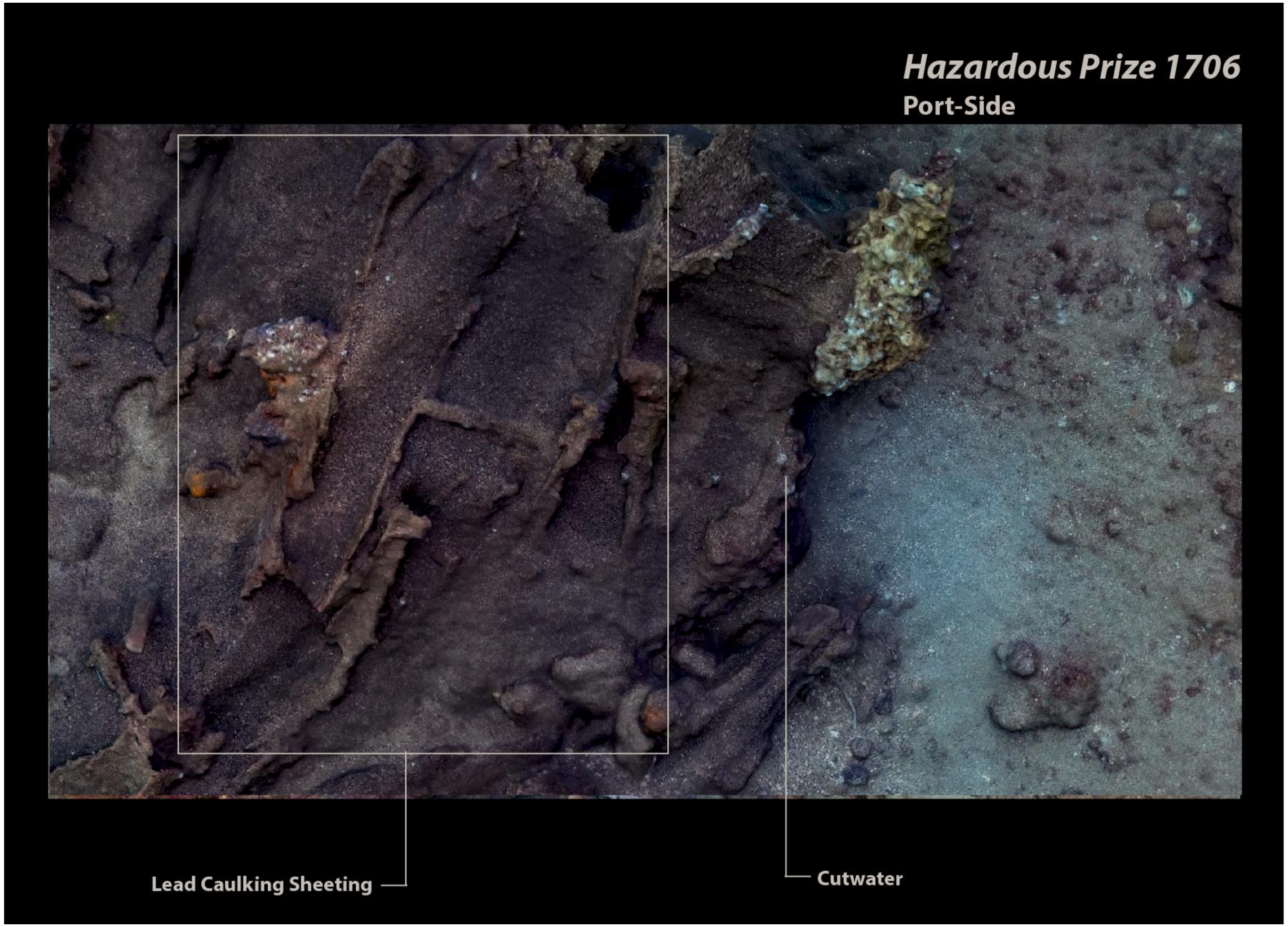


Figure 41. The image shows lead caulking sheeting at the bow section of the wreck. The image was generated with photogrammetry in Agisoft Metashape Pro v1.5 ® and rendered in 3DsMax®. The pictures were previously colour corrected with Adobe Lightroom® the image was edited in Adobe Photoshop® and Adobe Illustrator ® by the author of this thesis.

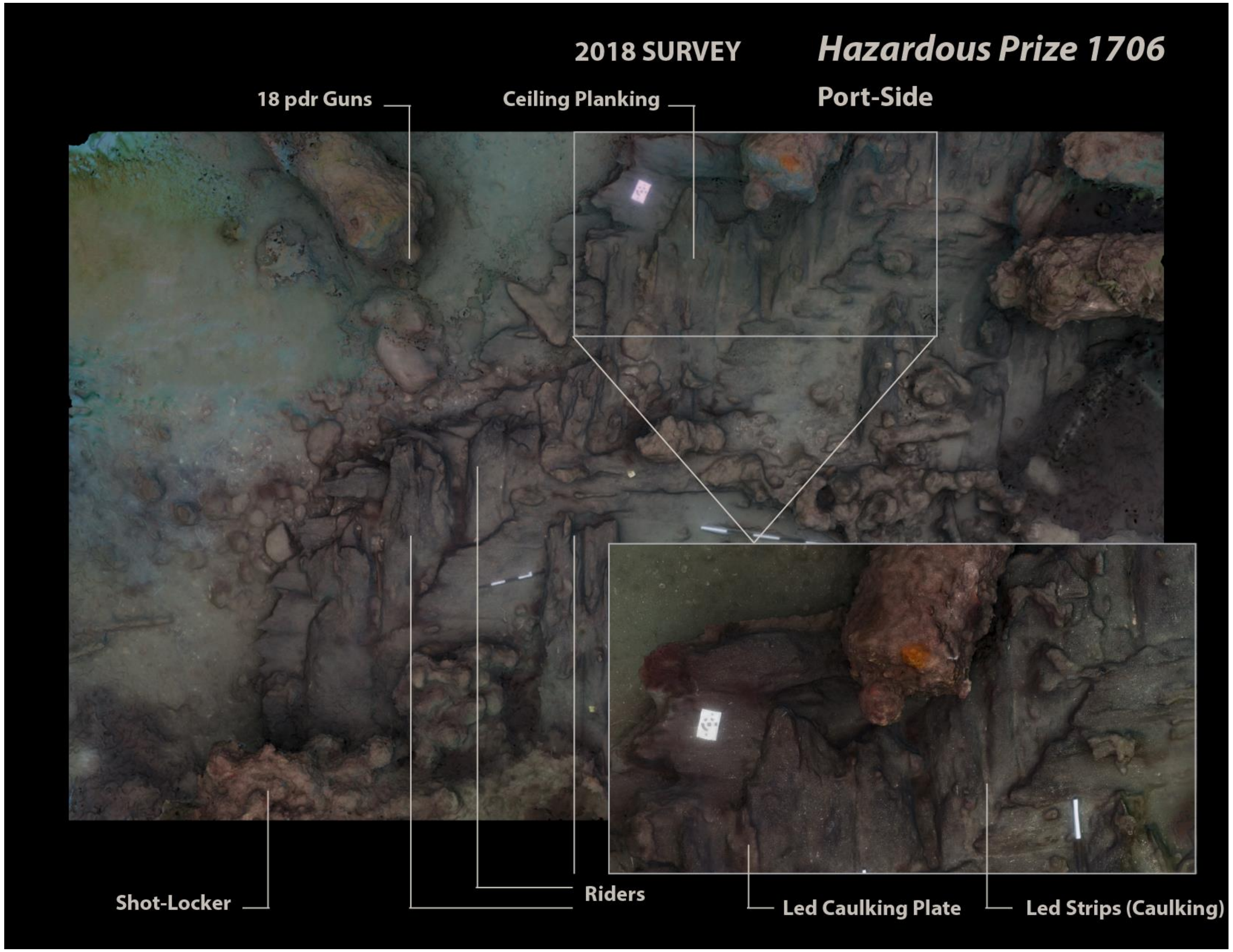


Figure 42. The image was generated with photogrammetry in Agisoft Metashape Pro v1.5 ® and rendered in 3DsMax®. The pictures were previously colour corrected with Adobe Lightroom® and the image was edited in Adobe Photoshop® and Adobe Illustrator ® by the author of this thesis.

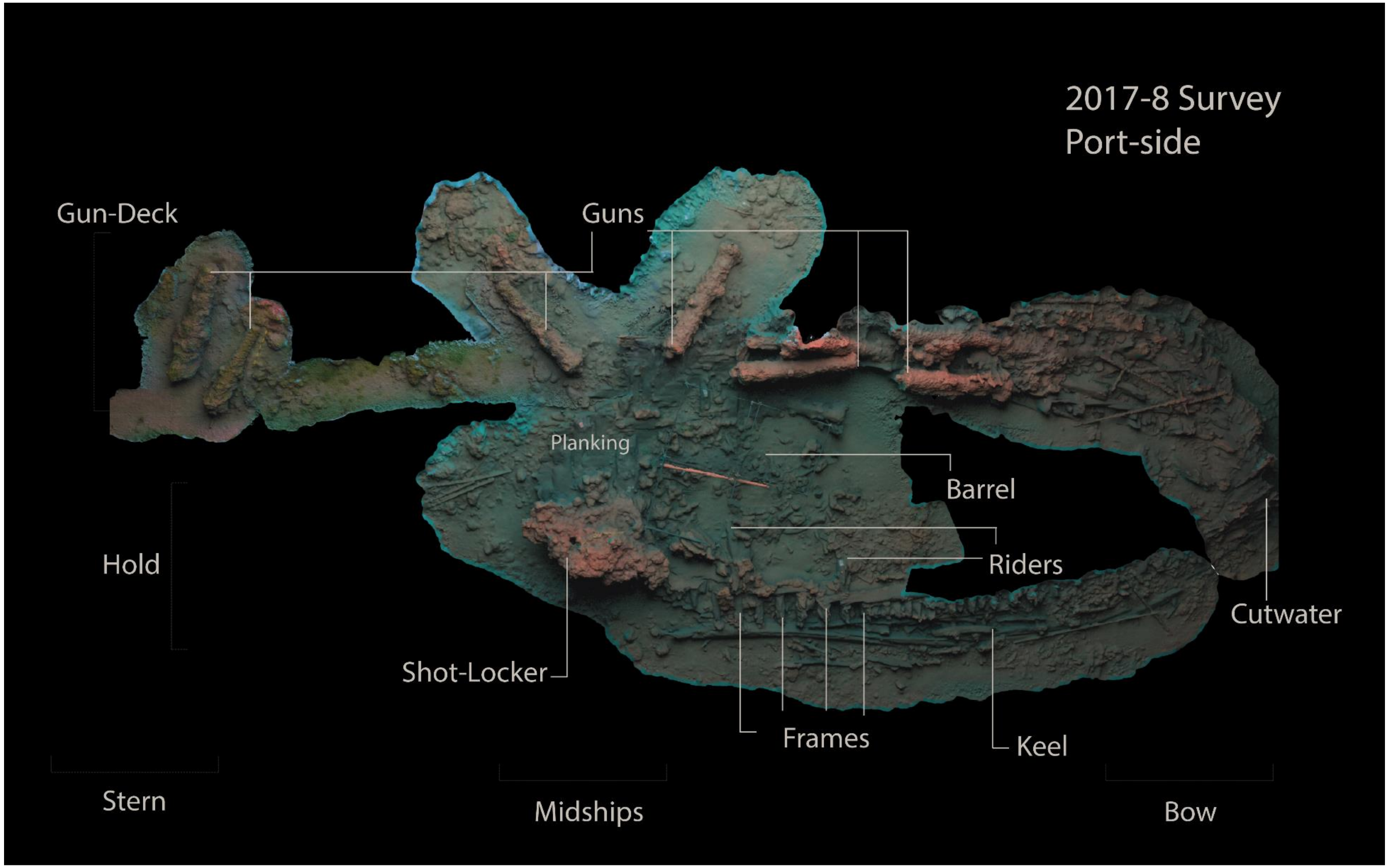


Figure 43. The image was generated with photogrammetry in Agisoft Metashape Pro v1.5 ® and rendered in 3DsMax®. The pictures were previously colour corrected with Adobe Lightroom® and the image was edited in Adobe Photoshop® and Adobe Illustrator ® by the author of this thesis.

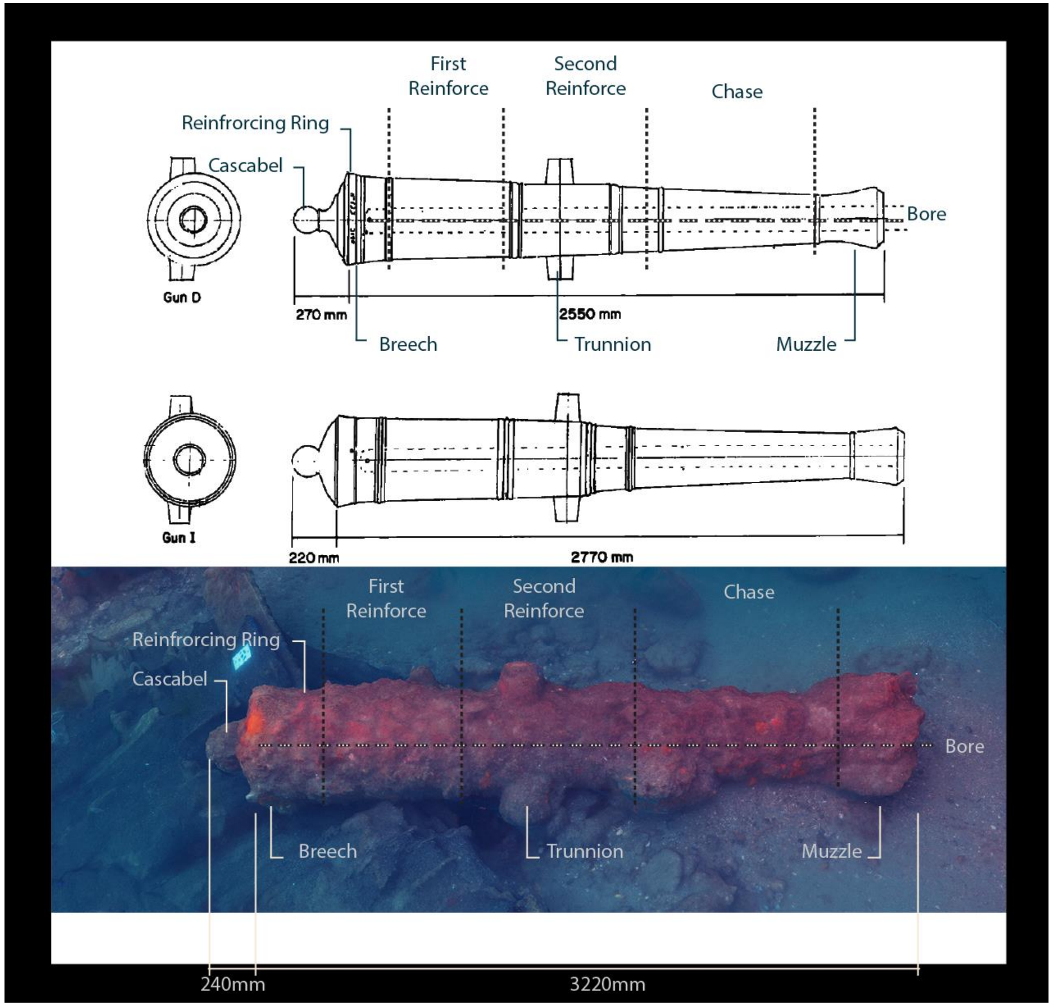


Figure 44. The image was generated with photogrammetry in Agisoft Metashape Pro v1.5 ® and rendered in 3DsMax®. The pictures were previously colour corrected with Adobe Lightroom® and the image was edited in Adobe Photoshop® and Adobe Illustrator ® by the author of this thesis.

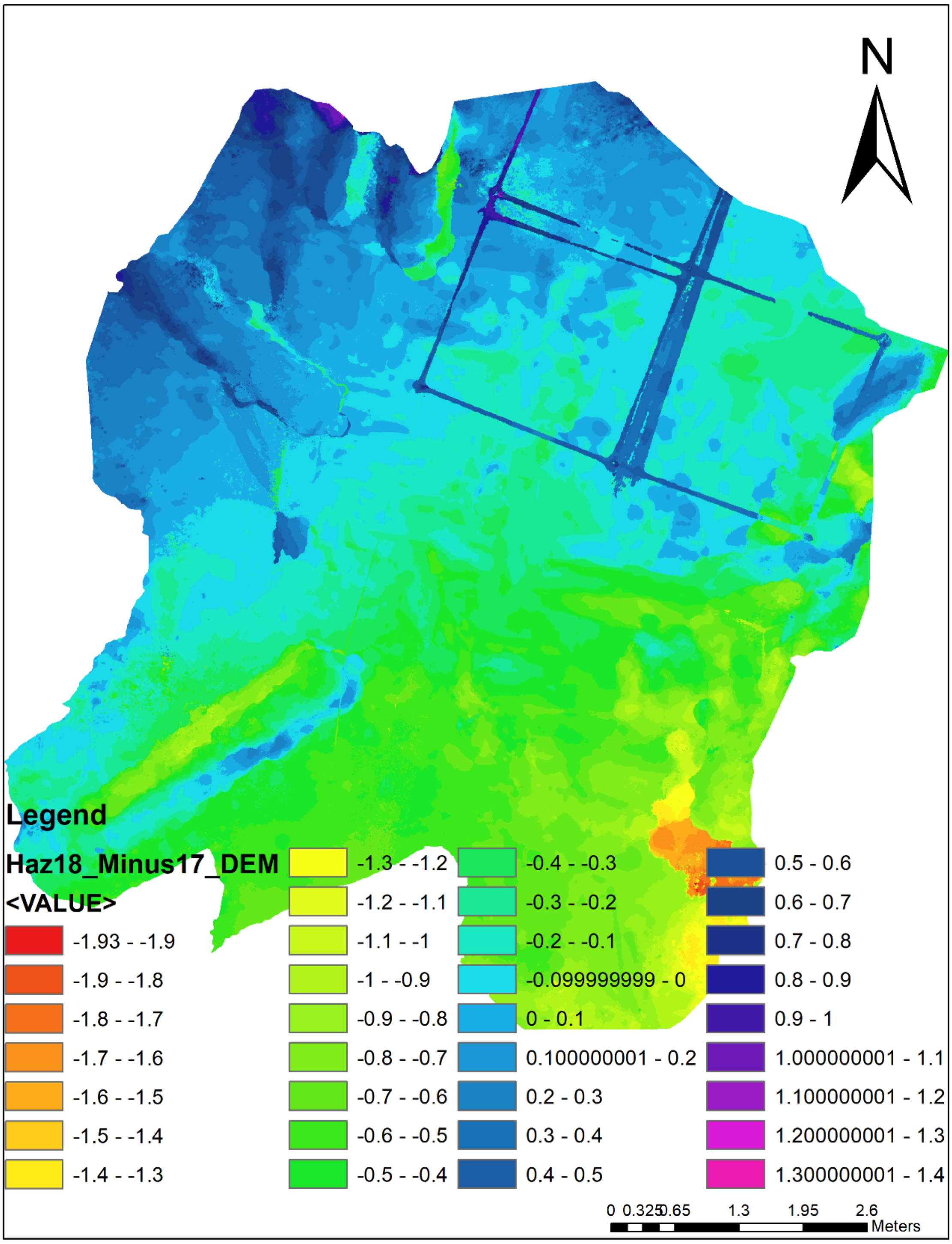


Figure 45. The figure presents a DEM from the 2017 survey, showing changes in the main area of the wreck site. The author of this thesis created the map in ArcMap10.5 ®

Figure 46. The figure presents a Hillshade of DEM from the 2017 survey, showing changes in the main area of the wreck site. The author of this thesis created the map in ArcMap10.5 ®

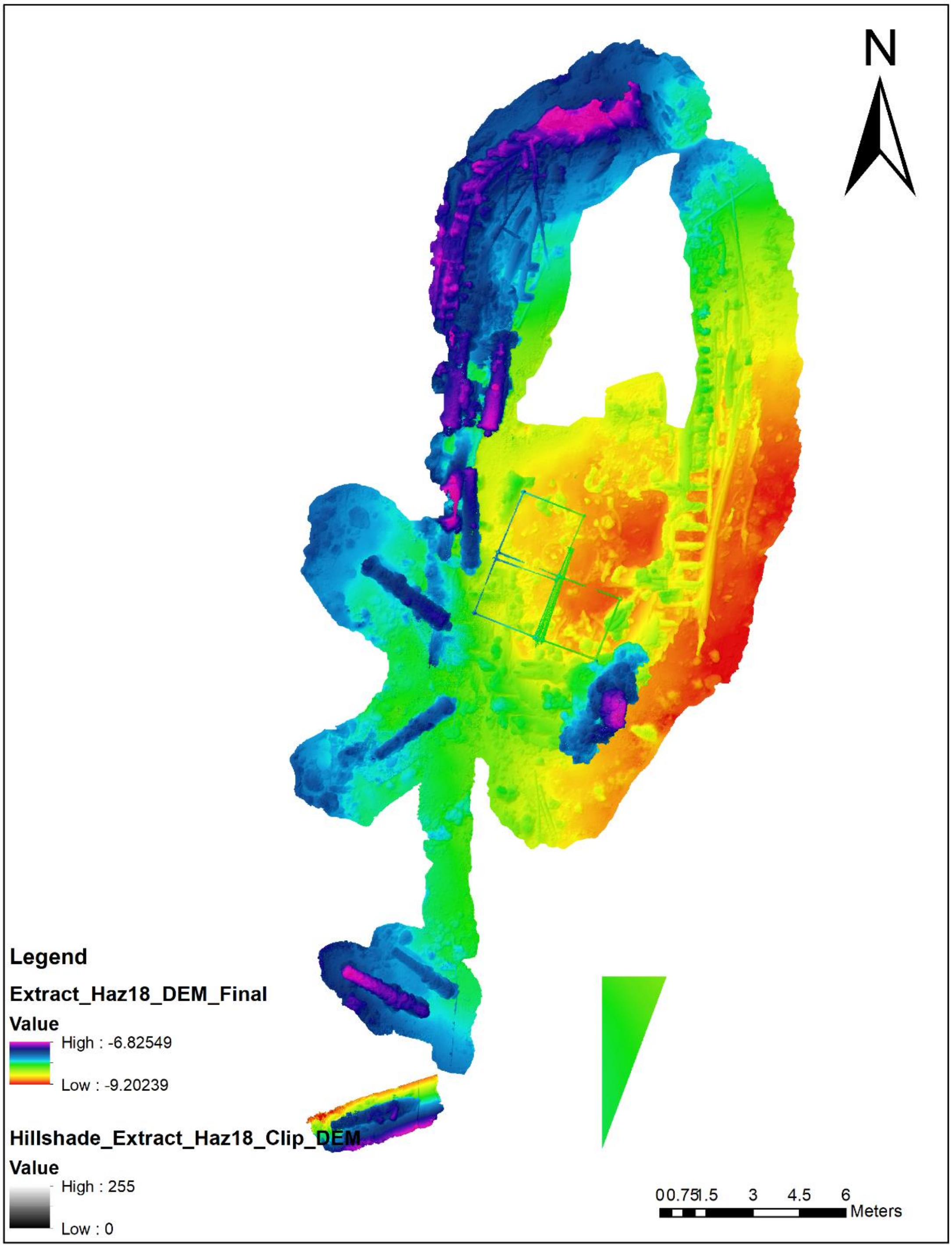


Figure 47. The figure presents a DEM from the combined 2017 and 2018 surveys, showing changes in the main area of the wreck site. The author of this thesis created the map in ArcMap10.5 ®

Figure 48. The figure presents a Hillshade DEM from the combined 2017 and 2018 surveys, showing changes in the main area of the wreck site. The author of this thesis created the map in ArcMap10.5 ®

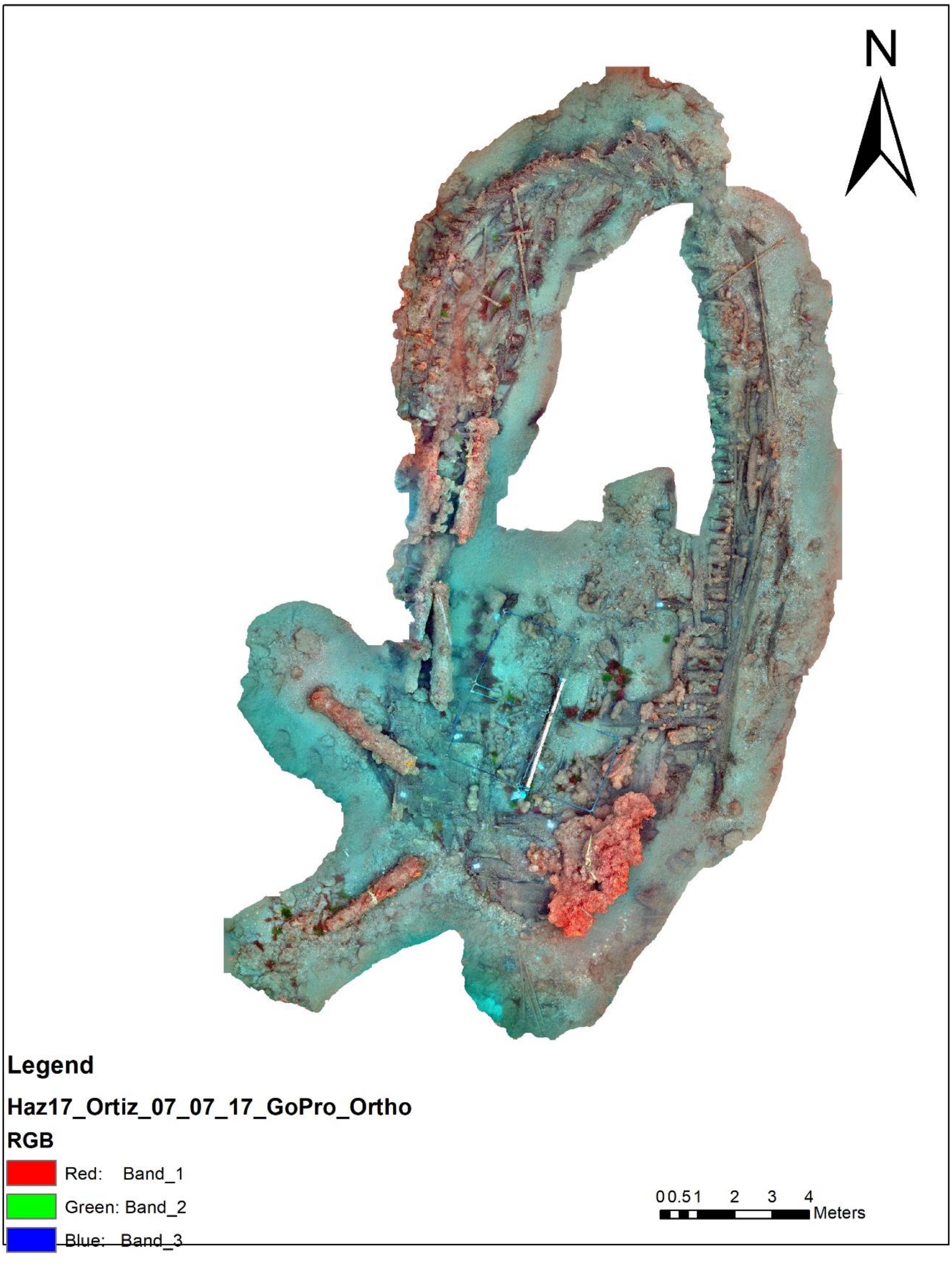


Figure 49. The figure presents an orthophoto from the 2017 survey, showing changes in the main area of the wreck site. The author of this thesis created the map in ArcMap10.5 ®

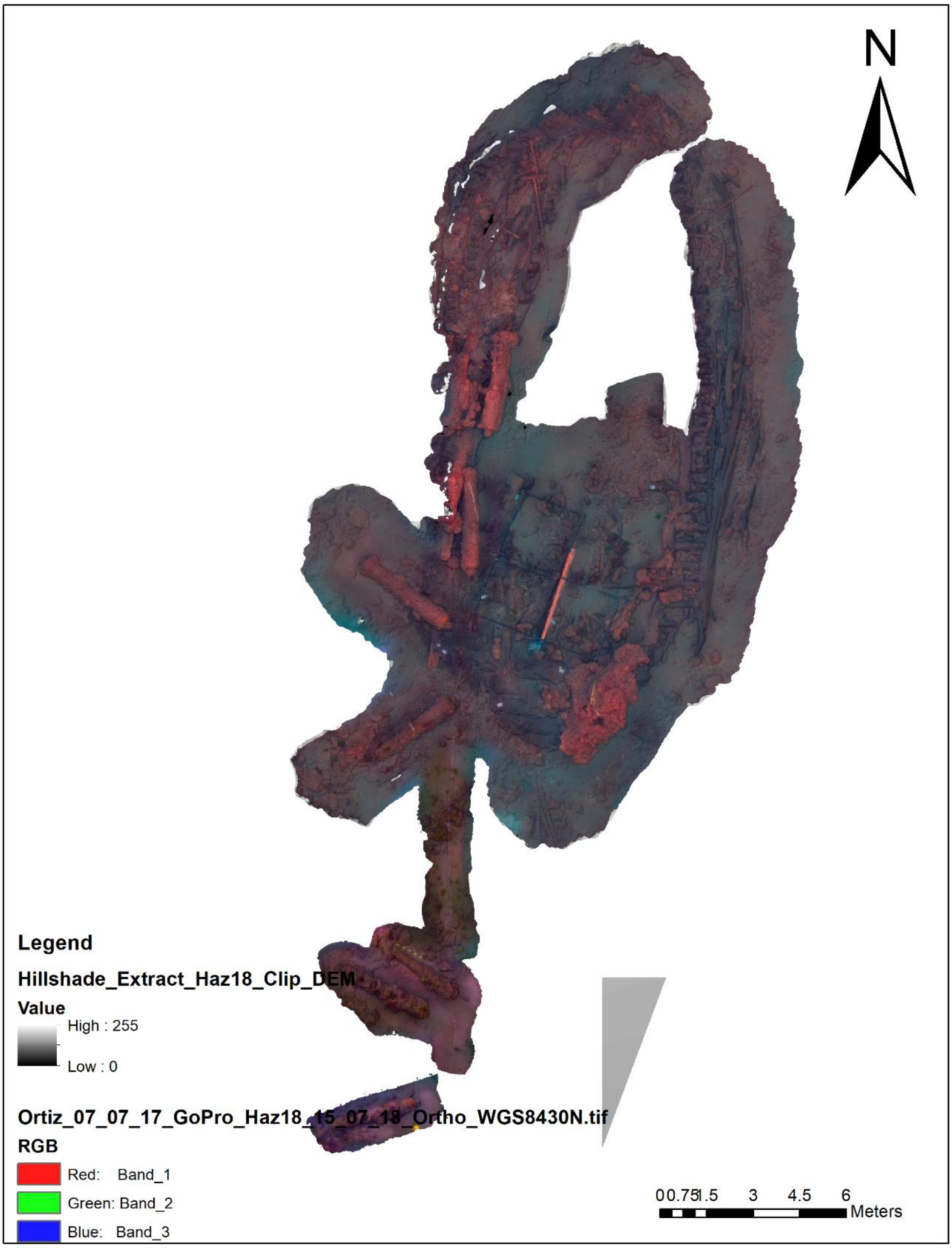


Figure 50. The figure presents an orthophoto from the combined 2017 and 2018 surveys, showing changes in the main area of the wreck site. The author of this thesis created the map in ArcMap10.5 ®

2.A.4 Fieldwork. *Hazardous* Prize 1699-1706

Figure 51. The picture shows a diver recording the *Hazardous* wreck. The author of this thesis took the picture on 7 July 2017.

Figure 52. WHPPG launching the rib from Bracklesham Bay on low tide, to a visit to *Hazardous*. The author of this thesis took the picture on 11 Nov 2015.

Figure 53. WHPPG diving on site during the excavation of 2017. Dave Johnston took the picture. The author of this thesis modified and enhanced the image.

B. *Rooswijk*1738-1740 (Chapter VII)

- Historical
- Geophysics
- Photogrammetry
- GIS Artefacts
- Fieldwork

2.B.1 Historical. *Rooswijk*1738-1740.

	Name	Location	Date	Tonnage
1	*Adelaar*	Barra, Hebrides, UK	1728	810
2	*Akerendam*	Ålesund, Norway	1725	850
3	*Amsterdam*	Hastings, UK	1748	1150
4	*Avonster (yatch)*	Hgalle, Sri Lanka	1659	360
5	*Banda*	Mauritius	1615	600-800
6	*Batavia*	Hout,am Abrolhos, Australia	1659	360
7	*Bennebroek*	Mtana River, South Africa	1713	800
8	*Boot*	Salcombe, Prawle Point, UK	1738	650
9	*Brederode*	Cape Agulhas, South Africa	1785	1150
10	*Brredenhof*	Strait Mozambique	1753	850
11	*Buitenzorg*	Waddenzee, Netherlands	1760	880
12	*Dolfiijn (yatch)*	Galle, Sri Lanka	1663	520
13	*Domburg*	Meob Bat, Namibia	1748	850
14	*Geldermalsen*	Riau Archipelago	1752	1150
15	*Geünieerde Provinciën*	Mauritus	1615	700
16	*Hercules (yacht)*	Galle, Sri Lanka	1661	540
17	*Hollandia*	Scilly Isles, UK	1743	1150
18	*Hoorn (yatch)*	Patagonia, Argentina	1615	110
19	*Huis te Kraaiestein*	Oude Kraal Bay, South Africa	1698	1154
20	*Kampen (yacht)*	Isle of Wight, UK	1627	300
21	*Kennermerland*	Shetland Islands, UK	1664	950

	Name	Location	Date	Tonnage
22	*Lastdrager (flute)*	Shetland Islands, UK	1653	640
23	*Leimuiden*	Cape Verde	1770	1150
24	*Lelie (galliot)*	Texel, Netherlands	1654	-
25	*Liefde (frigate)*	Shetland Islands, UK	1711	1009
26	*Mauritius*	Gabon, Guinea	1609	700
27	*Merestein (pinas)*	Jutten Island, South Africa	1702	826
28	*Middelburg*	Cape Rachado, Malaysia	1606	600
29	*Middelburg*	Saldanha Bay, South Africa	1781	1150
30	*Nassau (yacht)*	Cape Rachado, Malaysia	1606	320
31	*Nieuwerkerk*	Sulawesi, Indonesia	1748	1135
32	*Nieuw Rhoon*	Cape Town, South Africa	1776	1150
33	*Oosterland*	Cape Town, South Africa	1697	1123
34	*Prinses Maria*	Scilly Isles, UK	1686	1140
35	*Ravestein*	Maldives	1726	800
36	*Reigersdaal*	Springfontein, South Africa	1747	850
37	*Risdam (flute)*	Mersing, Malaysia	1727	520
38	*Rooswijk*	Goodwin Snads, UK	1740	850
39	*Slot ter Hoge*	Madeira	1724	850
40	*Vergulde Draak (yacht)*	Western Australia	1656	-
41	*Vis*	Tafelbaai, South Africa	1740	650
42	*Vliegend Hert*	Zeeland, Netherlands	1735	850
43	*Voetboog (flute)*	Pernambuco, Brazil	1700	595
44	*Waddinxveen*	Cape Town, South Africa	1697	751
45	*Witte Leeuw (yacht)*	Saint-Helena	1613	540

	Name	Location	Date	Tonnage
46	*Zeelelie*	Scilly Isles, UK	1795	1150
47	*Zeepaard*	Ireland	1665	400
48	*[Zee] rob*	Texel, Netherlands	1640	-
49	*Zeewijk*	Houtman Abrolhos, Australia	1727	850
50	*Zuiddrop*	Western Australia	1712	1152

Table 6. The list of VOC shipwrecks that have been located and worked on by Commercial Salvage companies and/or Archaeological Research. The table in based on (Van Duivenvorde 2015:144–45)

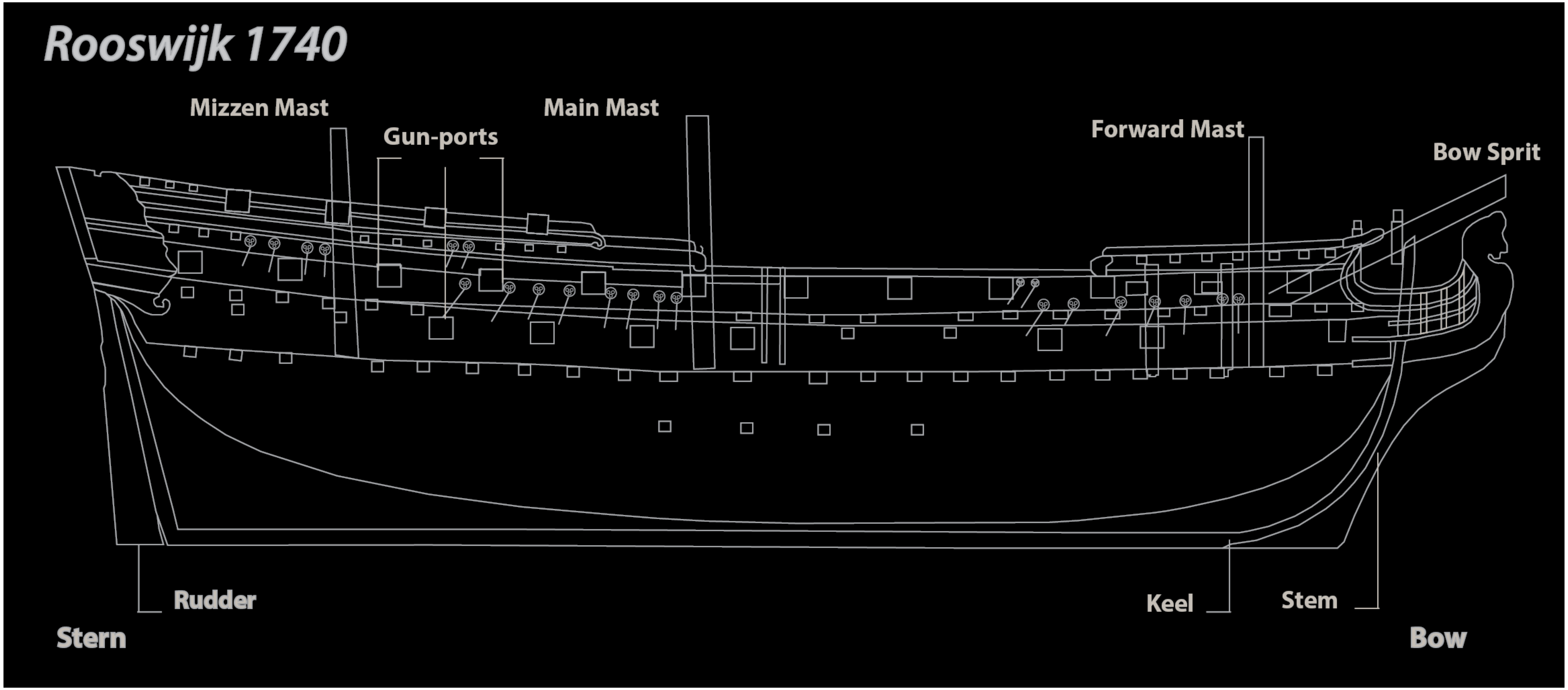


Figure 54. The image shows a hypothetical profile of the *Rooswijk1740* is based on the Bentam plans from 1742 (Bentam 1742b)**. The lines were drawn and captioned by the author of this thesis.**

Figure 55. The Island of Onrust near Batavia (Jakarta) (Storck 1699)**. Probably the port to which the *Rooswijk*arrived on its maiden journey and the point that it was heading before she wrecked.**

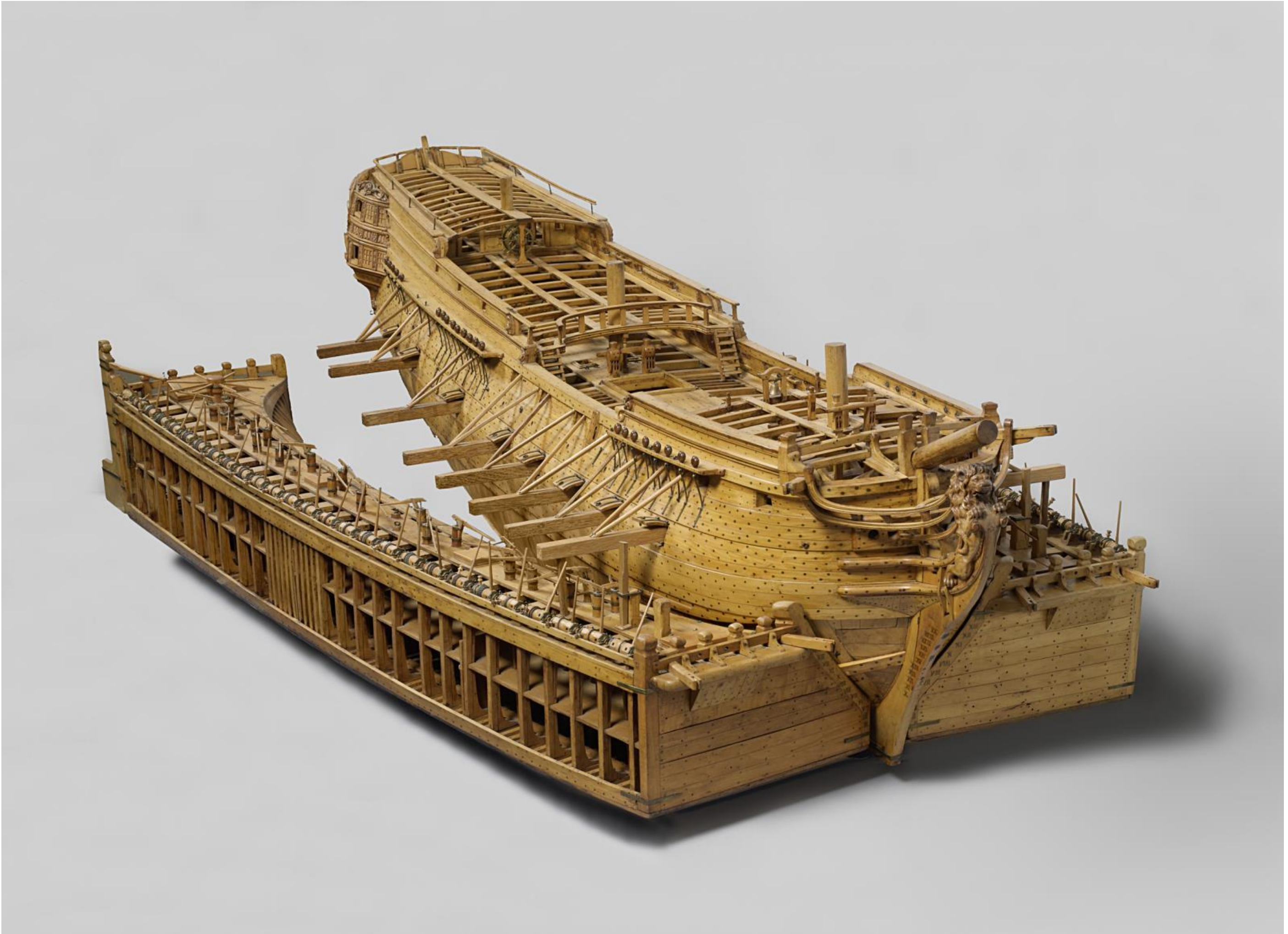


Figure 56. Boat model based on Charles Bentam 151 ft VOC *retourschip* (Bentam 1742a, 1742b)**. The original boat model is held at the Rijksmuseum, Amsterdam.**

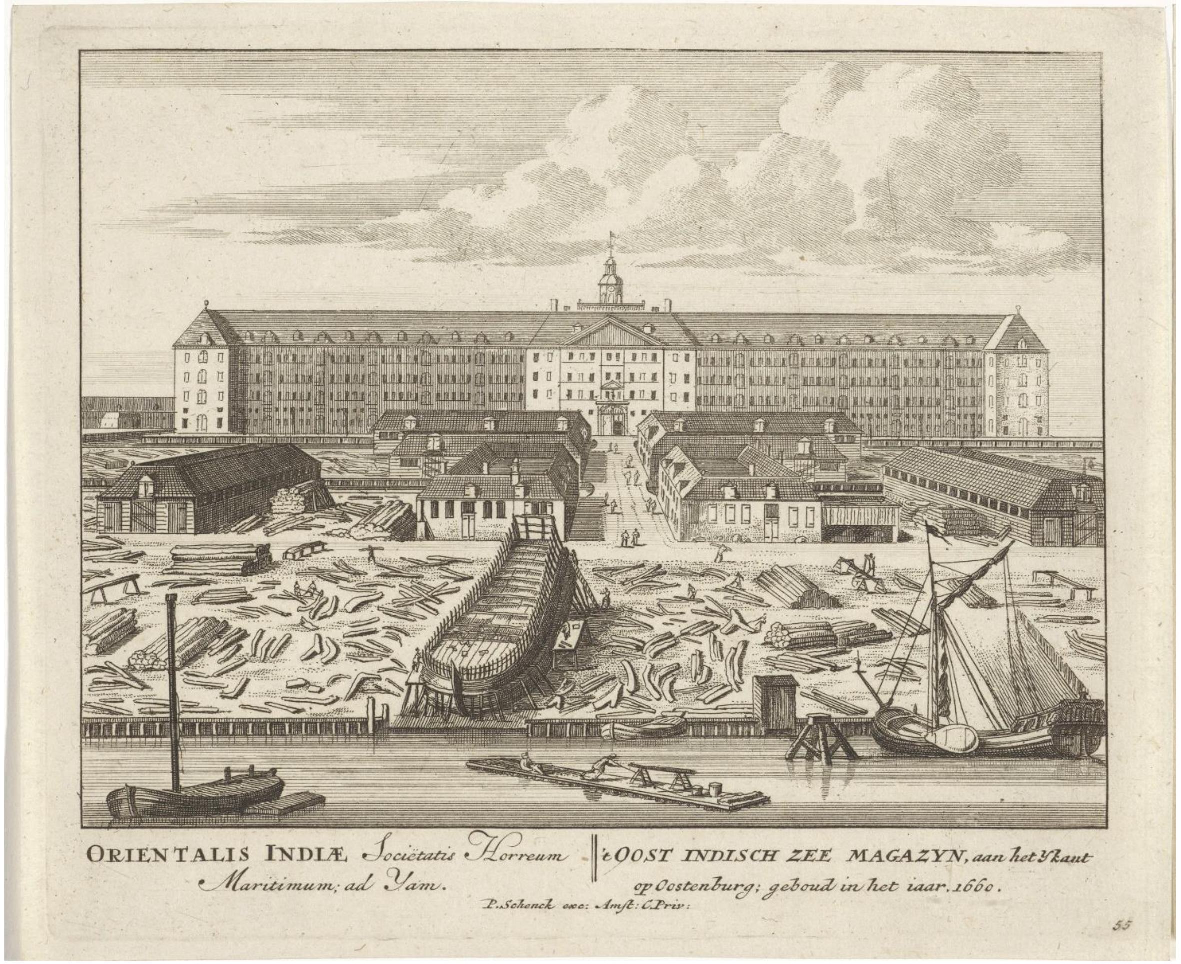


Figure 57. The figure shows the process shipbuilding taking part in Oostenburg shipyard, in Amsterdam. The original engraving is dated close to 1660 (Uknown 1725)**. The original engraving is kept at the Rijksmuseum in Amsterdam.**

2.B.2 Geophysics. *Rooswijk*1738-1740

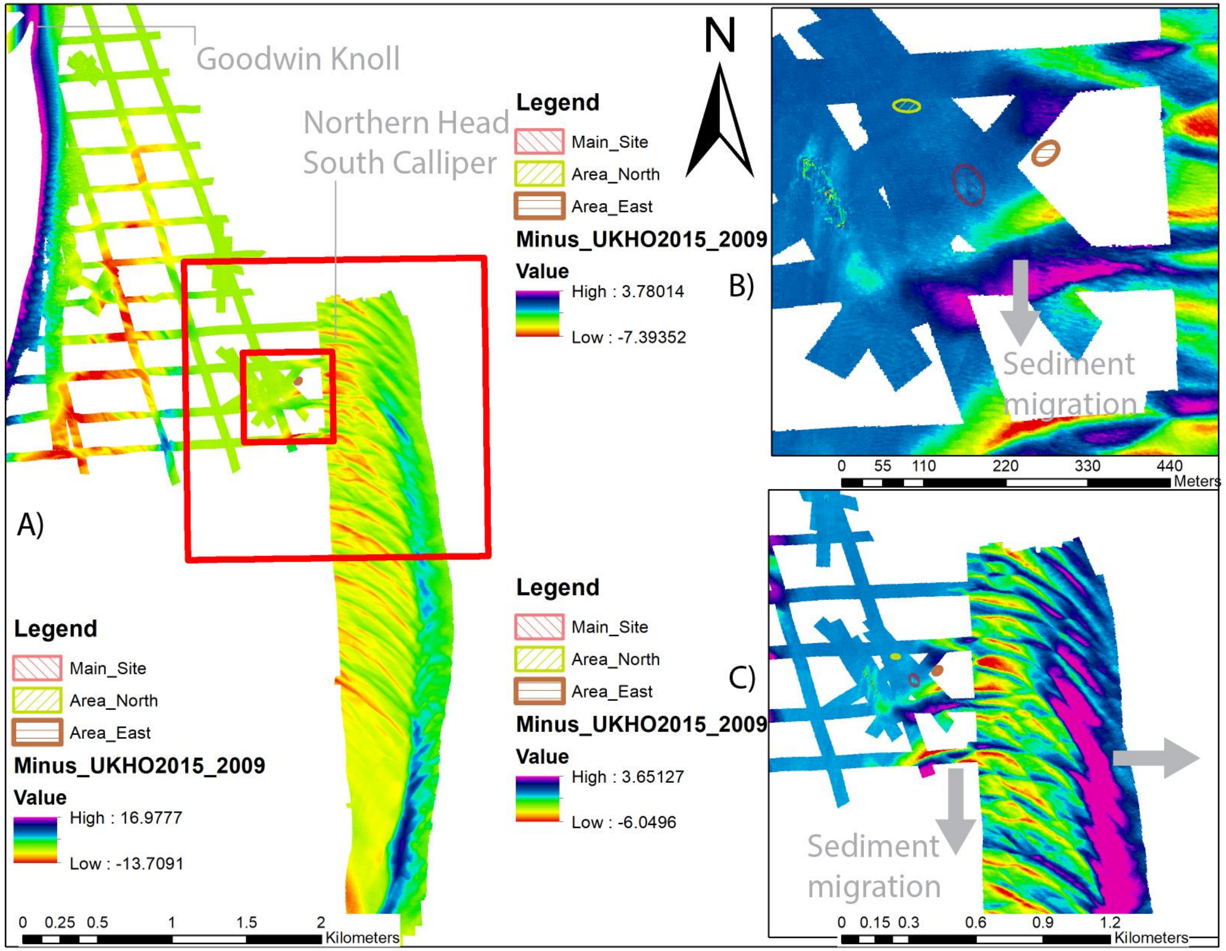


Figure 58. The figure shows a short time-lapse from 2009 to 2015 based on UKHO data (UKHO 2018)**. A) An overall view of the Northern Head of South Calliper and Goodwin Knoll. B) Close up of the *Rooswijk* designated area, showing sediment migration direction. C) Close up of Northern Head of South Calliper, showing sediment migration direction. The author of this thesis created the map in ArcMap 10.5®.**

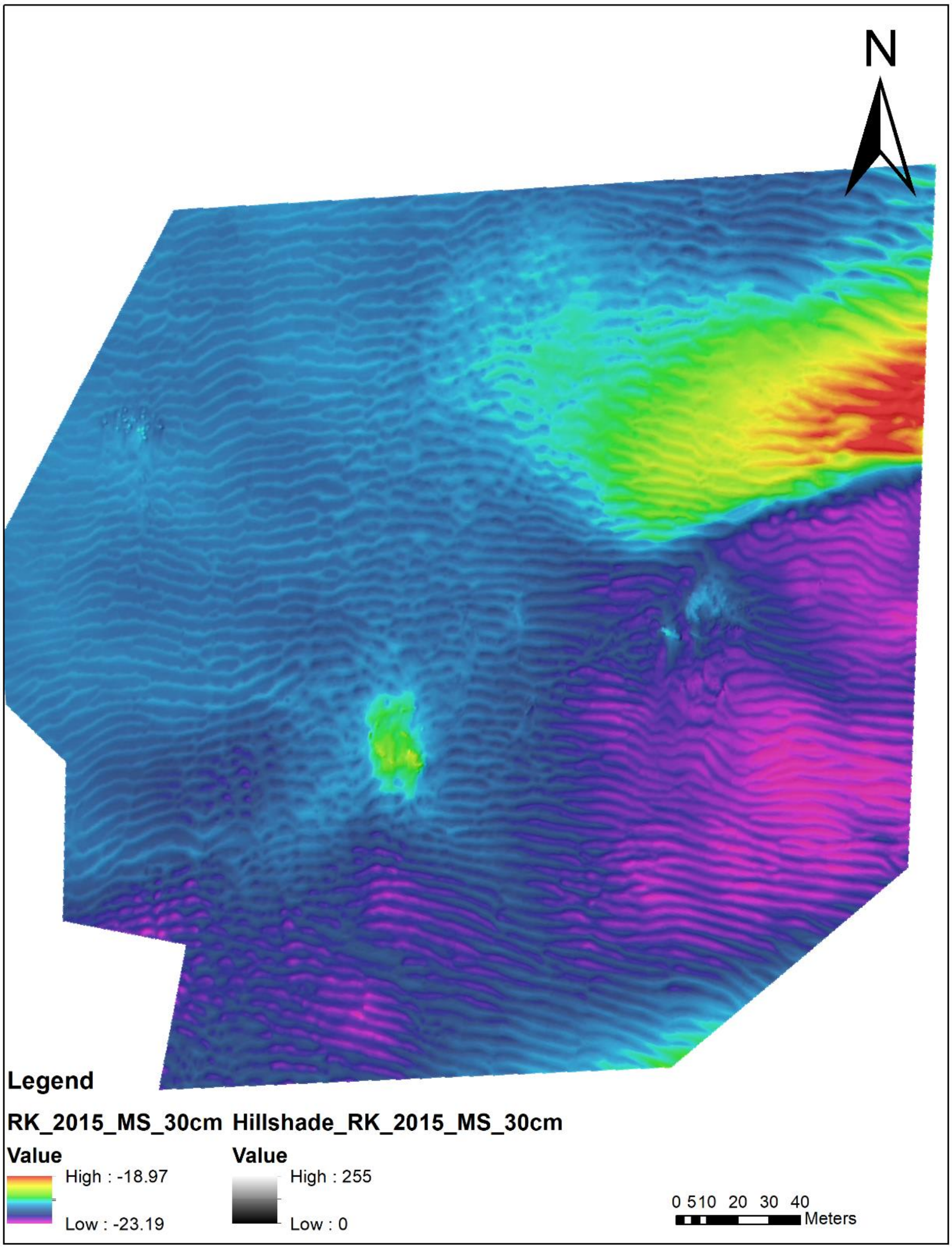


Figure 59. The figure shows a MBES surveys of the *Rooswijk* site in 2015. The data collection was carried out by Swathe Services, commissioned by RCE and managed by Trendarch. The author of this thesis created the maps in ArcMap 10.5®.

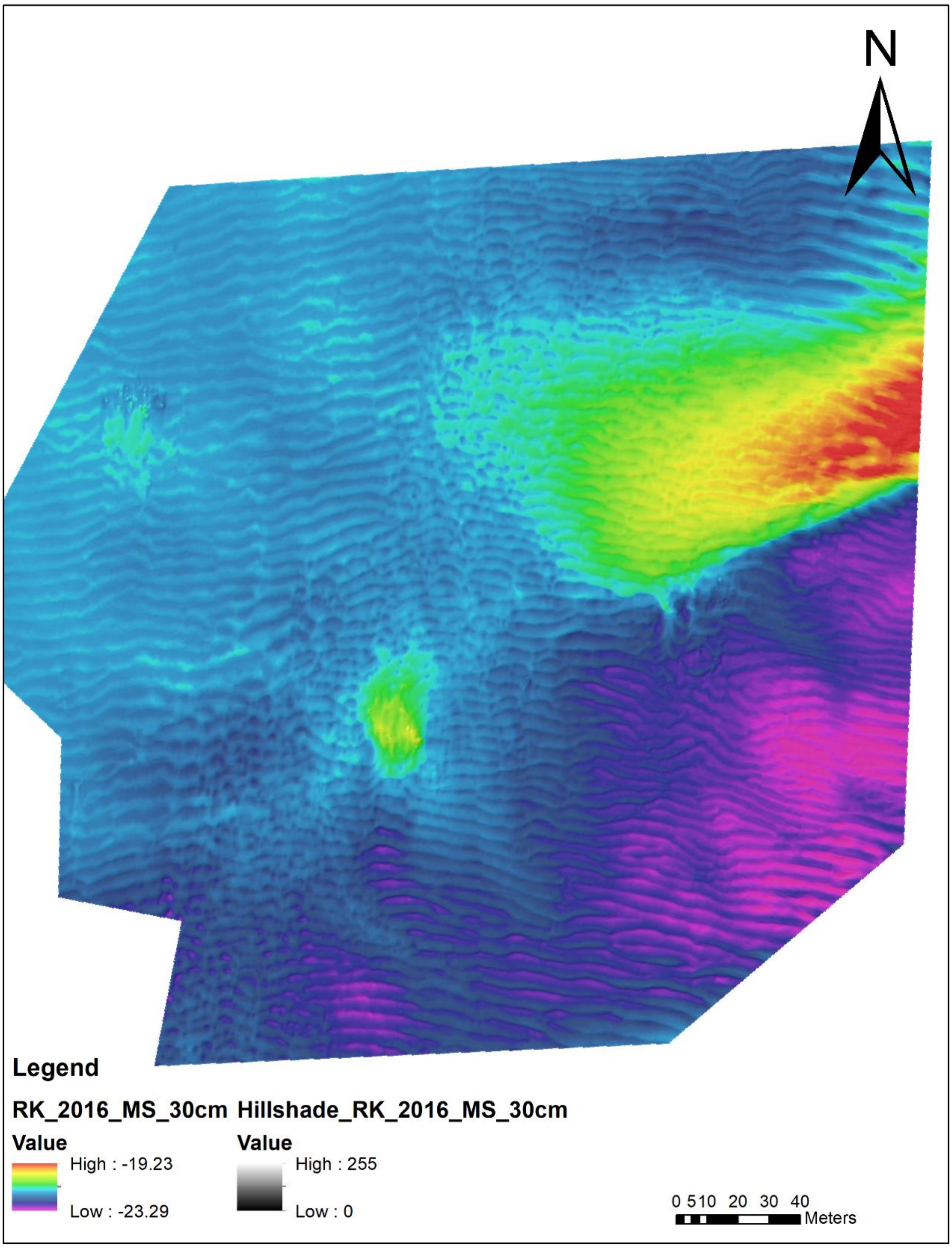


Figure 60. The figure shows a MBES surveys of the *Rooswijk* site in 2016. The data collection was carried out by MSDS Marine Ltd and Swathe Services, commissioned by RCE. The author of this thesis created the maps in ArcMap 10.5®.

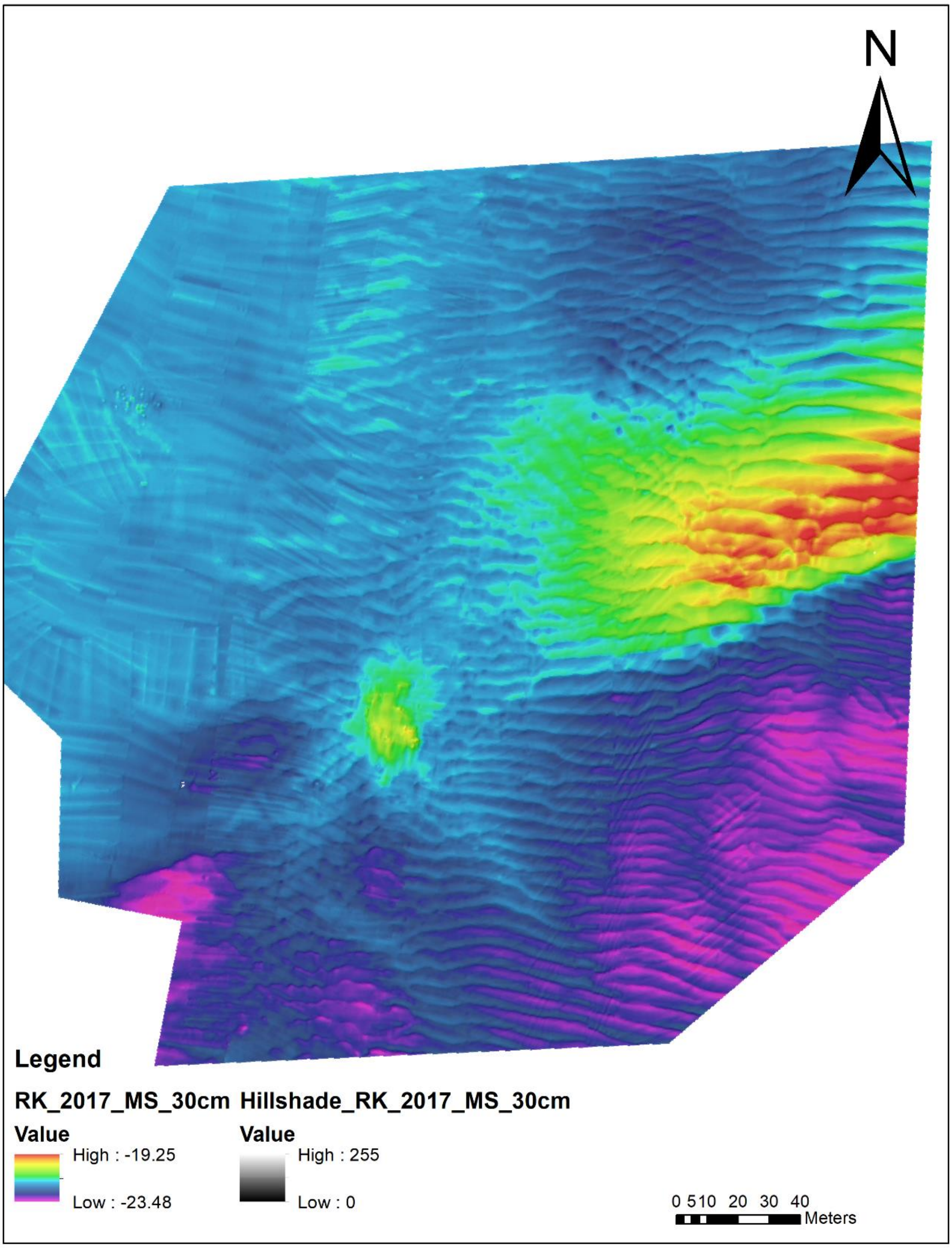


Figure 61. The figure shows a MBES surveys of the *Rooswijk* site in 2017. The data collection was carried out by MSDS Marine Ltd and Swathe Services, commissioned by HE and managed by PAS. The author of this thesis created the maps in ArcMap 10.5®.

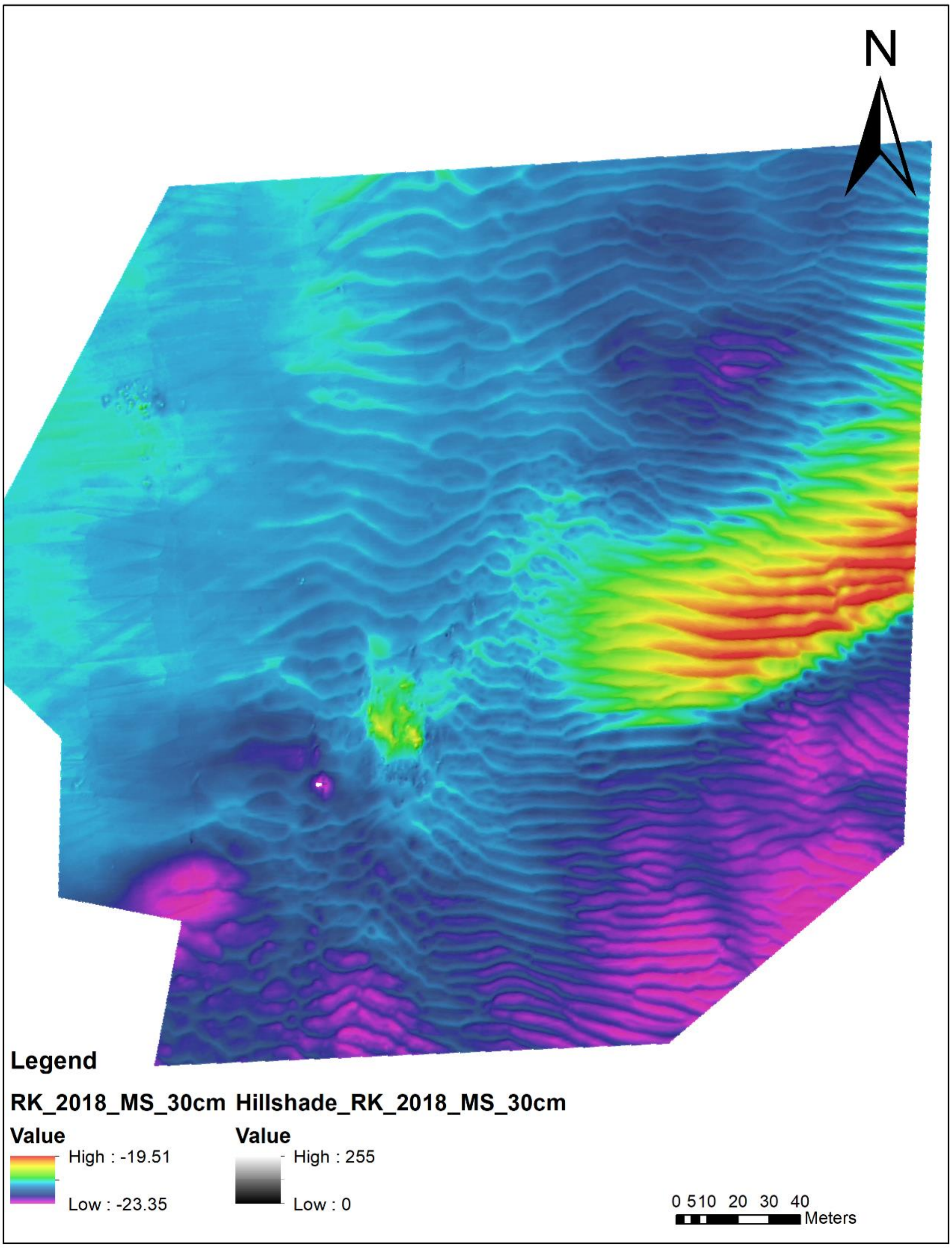


Figure 62. The figure shows a MBES surveys of the *Rooswijk* site in 2018. The survey was carried out by Swathe Services and MSDS Marine Ltd, commissioned by HE and managed by PAS. The data was kindly provided by PAS. The author of this thesis created the maps in ArcMap 10.5®.

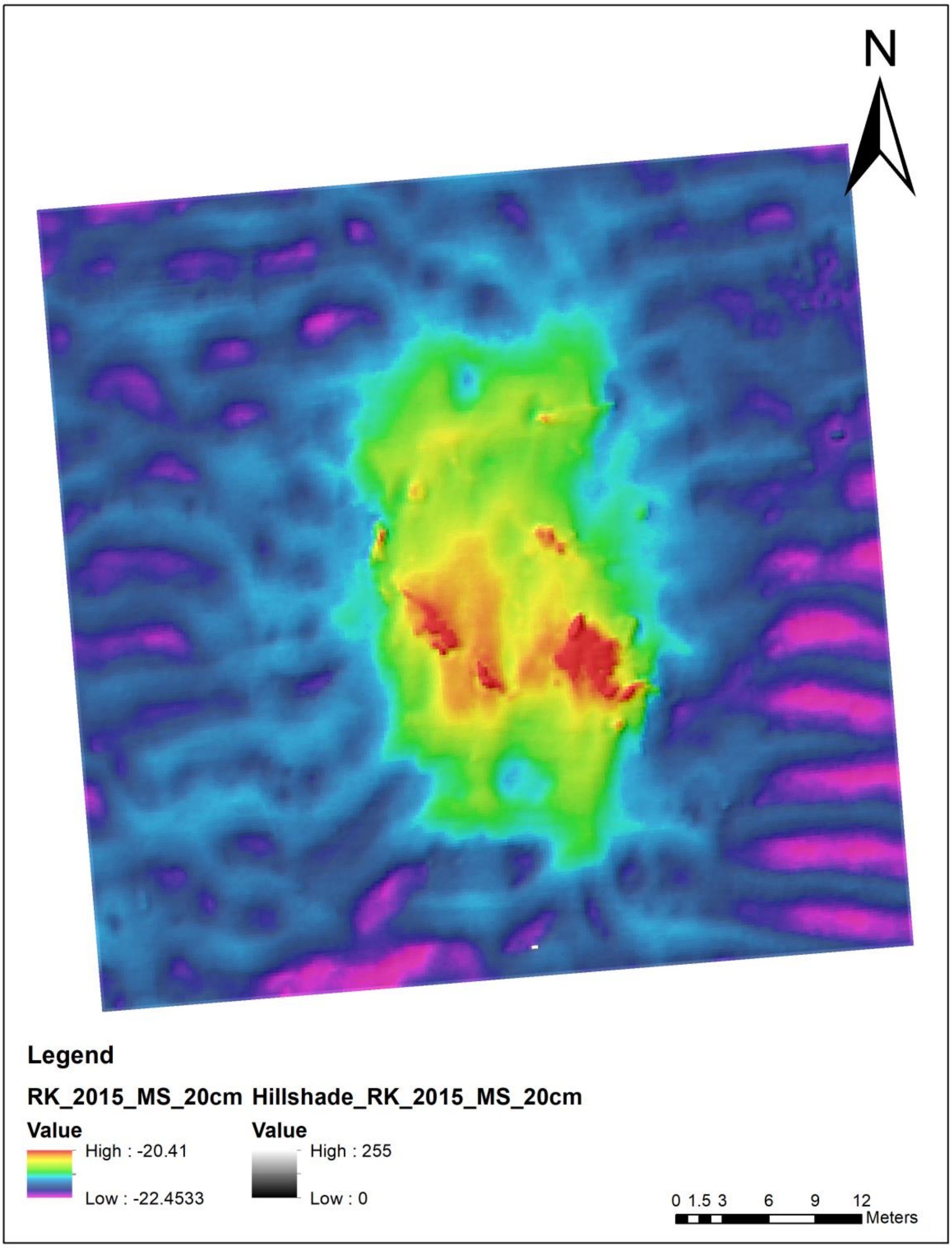


Figure 63. The figure shows the West Site MBES surveys of the *Rooswijk* site in 2015. The data collection was carried out by Swathe Services, commissioned by RCE and managed by Trendarch. The author of this thesis created the maps in ArcMap 10.5®.

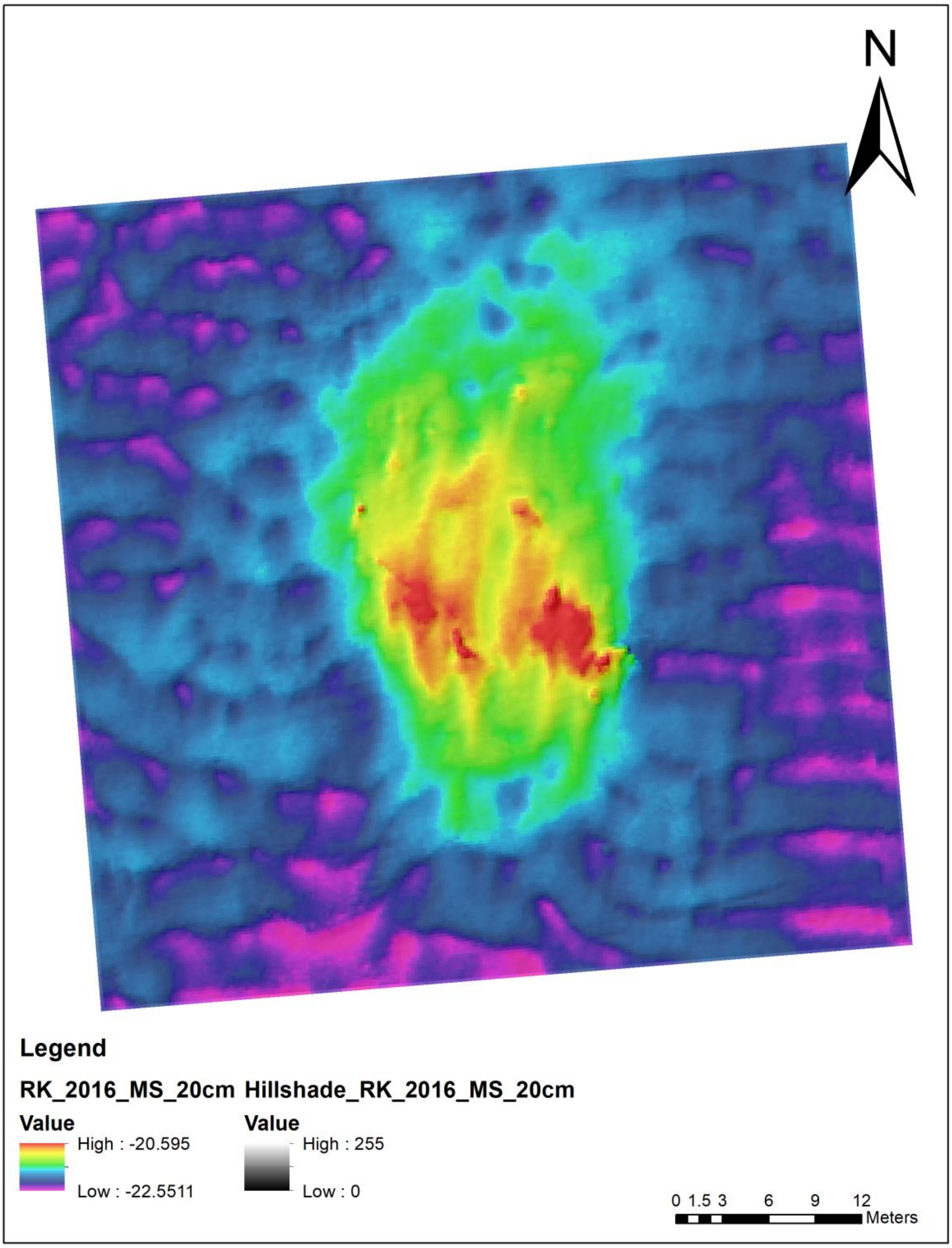


Figure 64. The figure shows the West Site MBES surveys of the *Rooswijk* site in 2016. The data collection was carried out by MSDS Marine Ltd and Swathe Services, commissioned by RCE. The author of this thesis created the maps in ArcMap 10.5®.

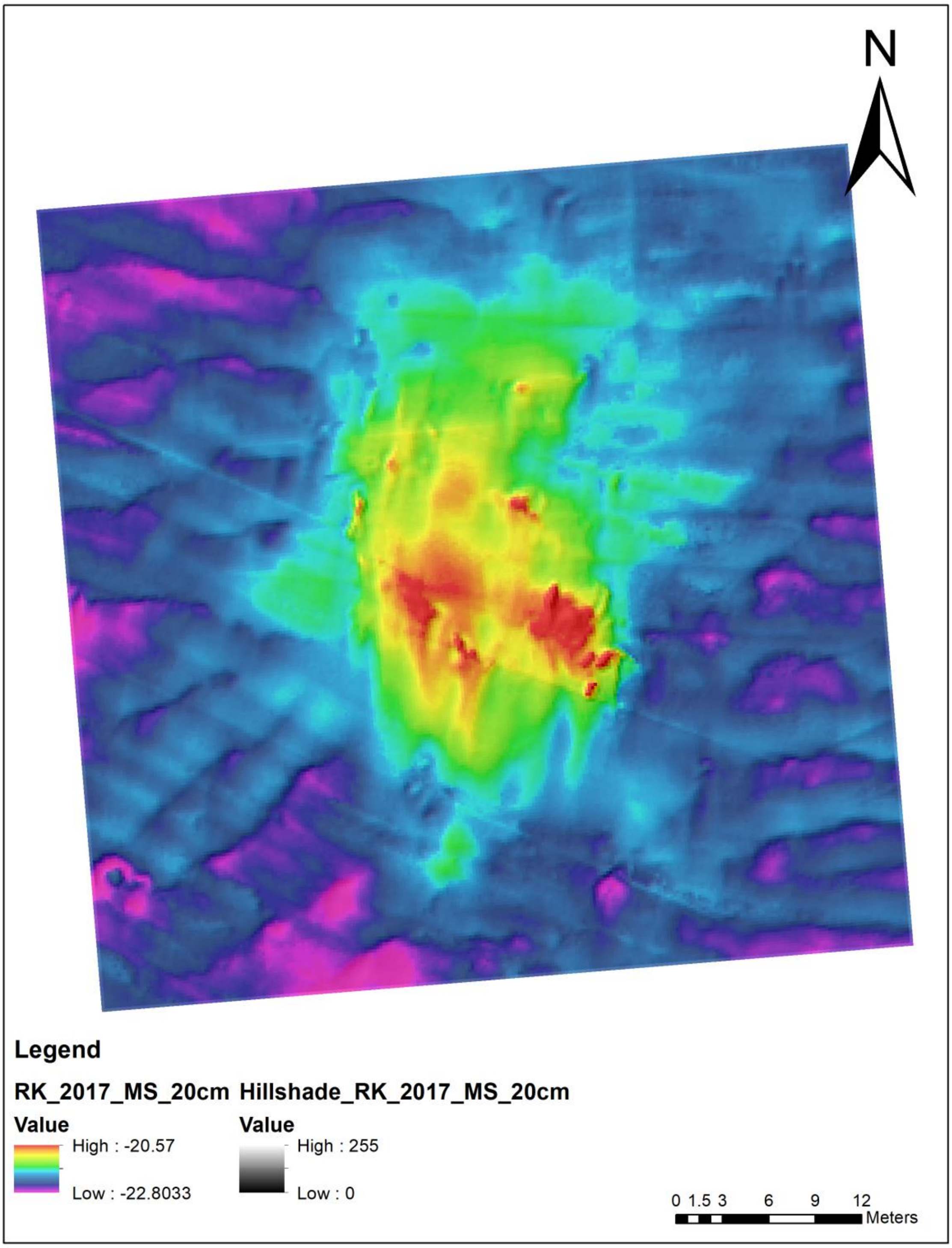


Figure 65. The figure shows the West Site MBES surveys of the *Rooswijk* site in 2017. The data was kindly provided by PAS. The data collection was carried out by MSDS Marine Ltd and Swathe Services, commissioned by HE and managed by PAS. The author of this thesis created the maps in ArcMap 10.5®.

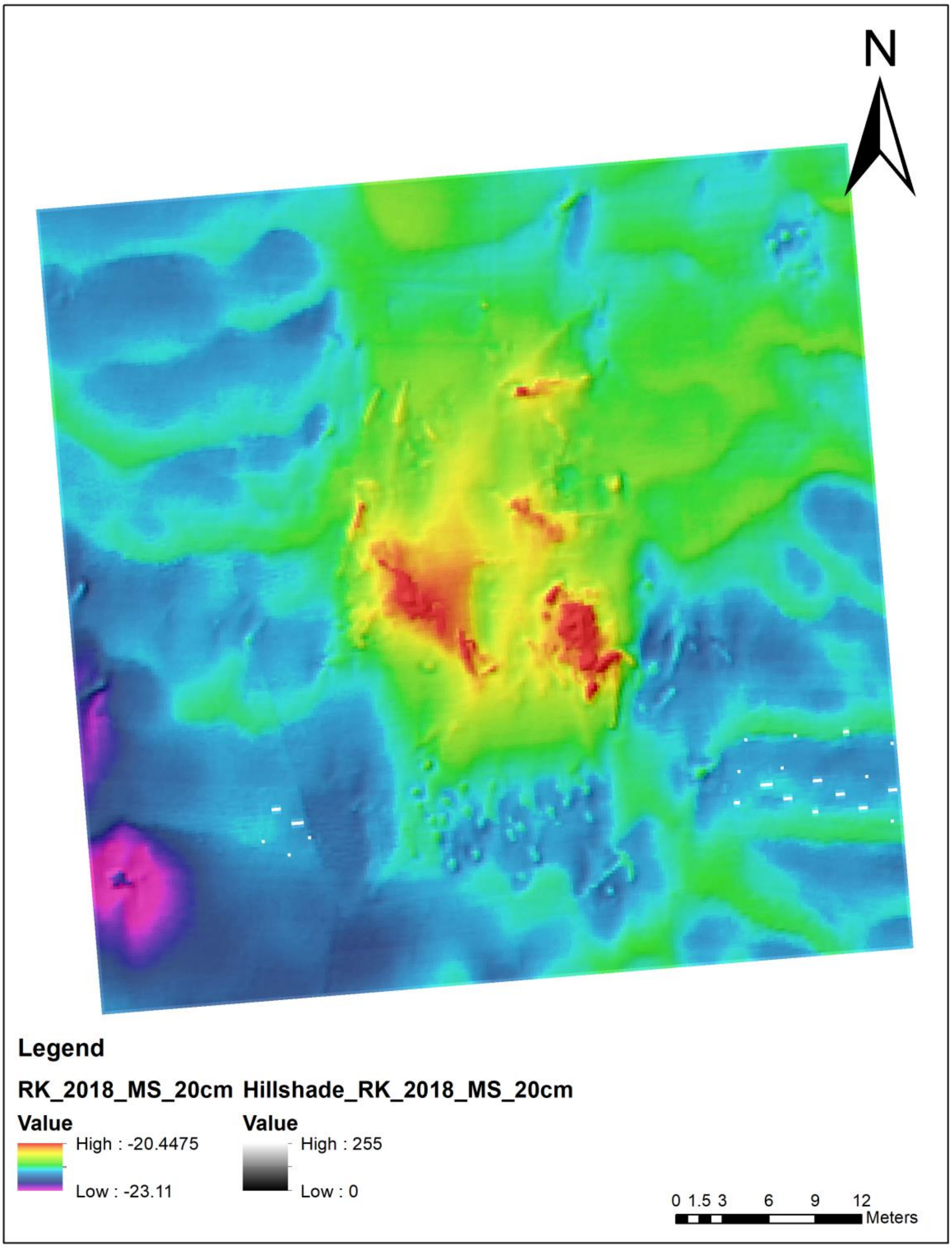


Figure 66. The figure shows the West Site MBES surveys of the *Rooswijk* site in 2018. The data was kindly provided by PAS. The data collection was carried out by MSDS Marine Ltd and Swathe Services, commissioned by HE and managed by PAS. The author of this thesis created the maps in ArcMap 10.5®.

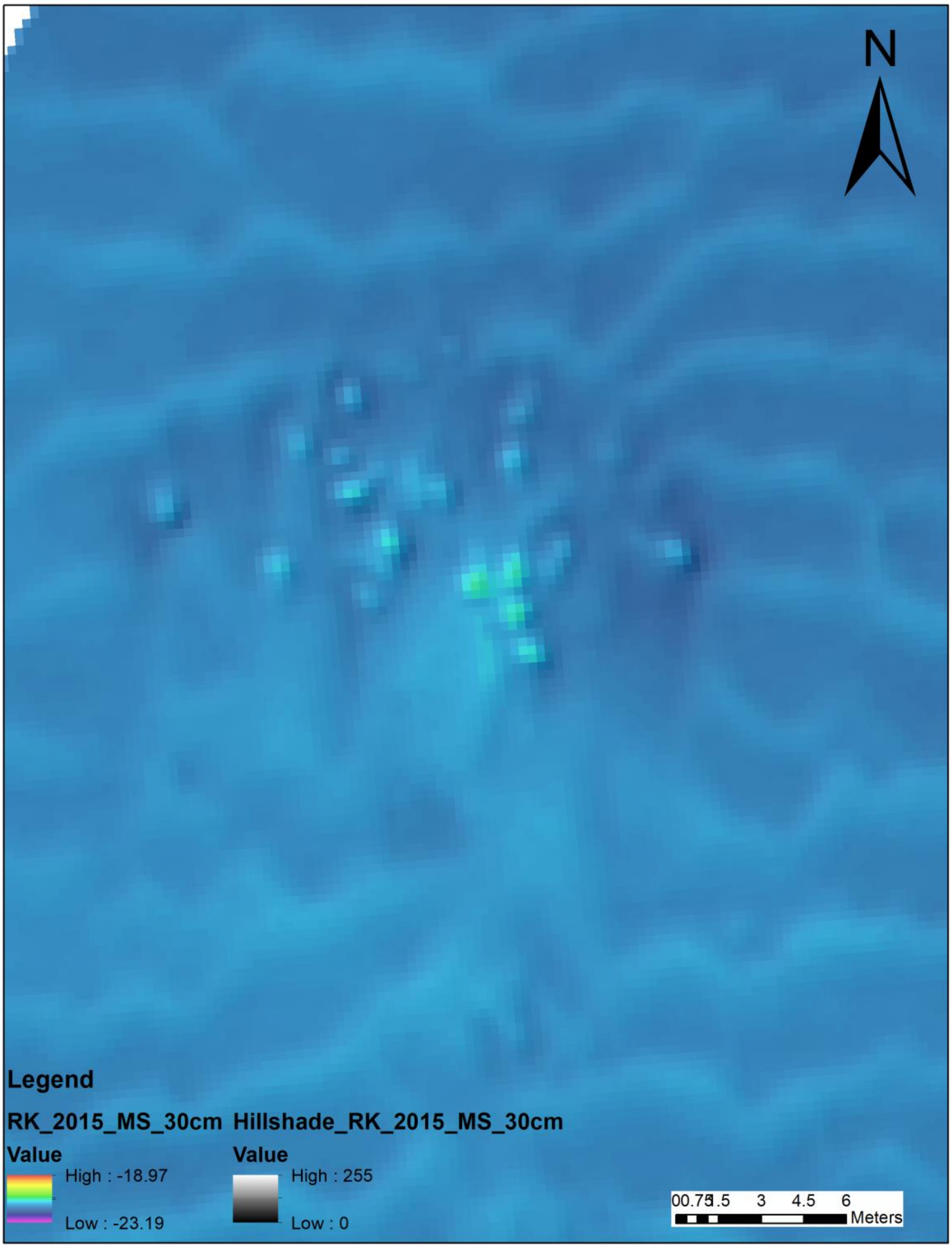


Figure 67. The figure shows the North Site MBES surveys of the *Rooswijks* ite in 2015. The data collection was carried out by Swathe Services, commissioned by RCE and managed by Trendarch. The author of this thesis created the maps in ArcMap 10.5®.

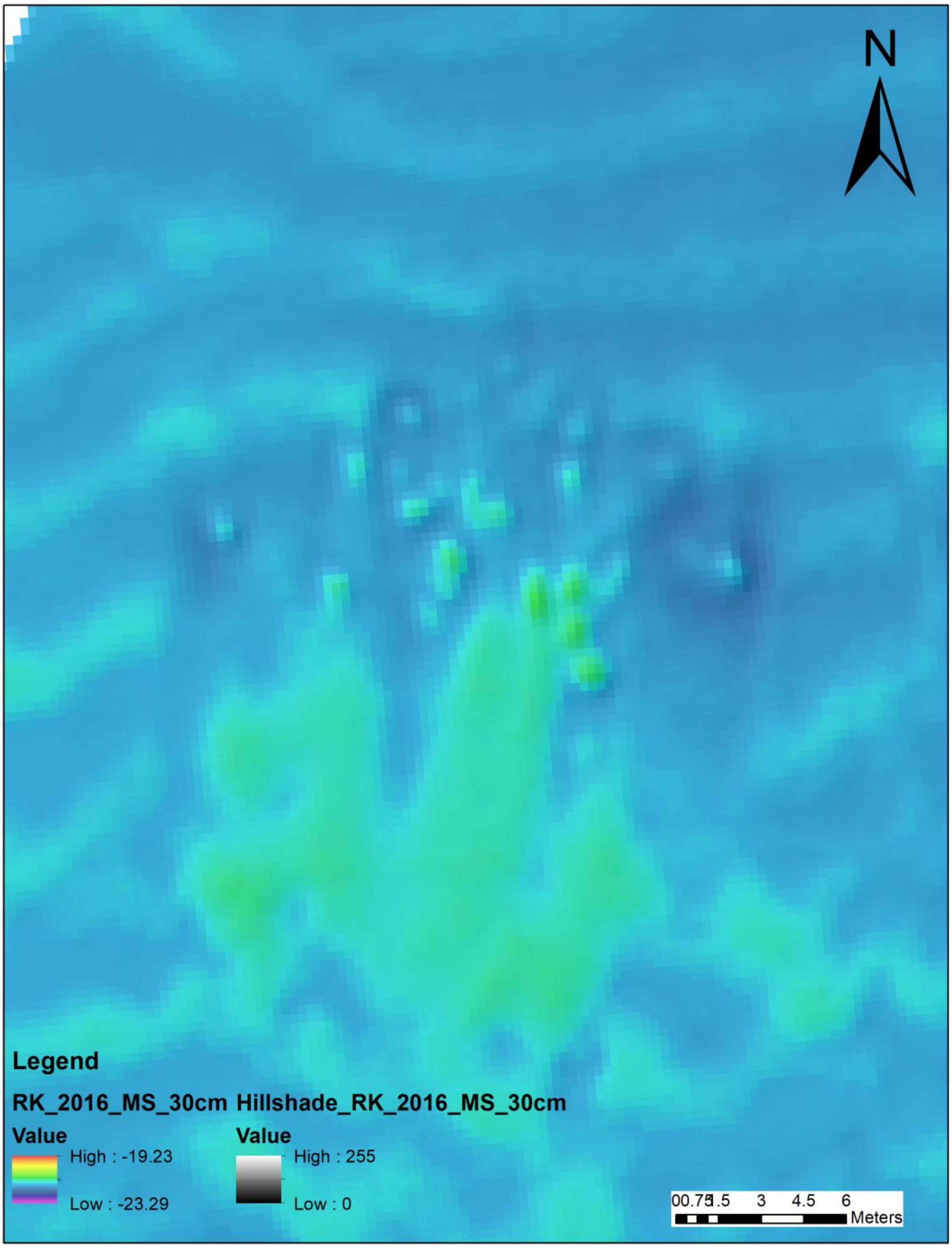


Figure 68. The figure shows the North Site MBES surveys of the *Rooswijk* site in 2016. The data collection was carried out by MSDS Marine Ltd and Swathe Services, commissioned by RCE. The author of this thesis created the maps in ArcMap 10.5®.

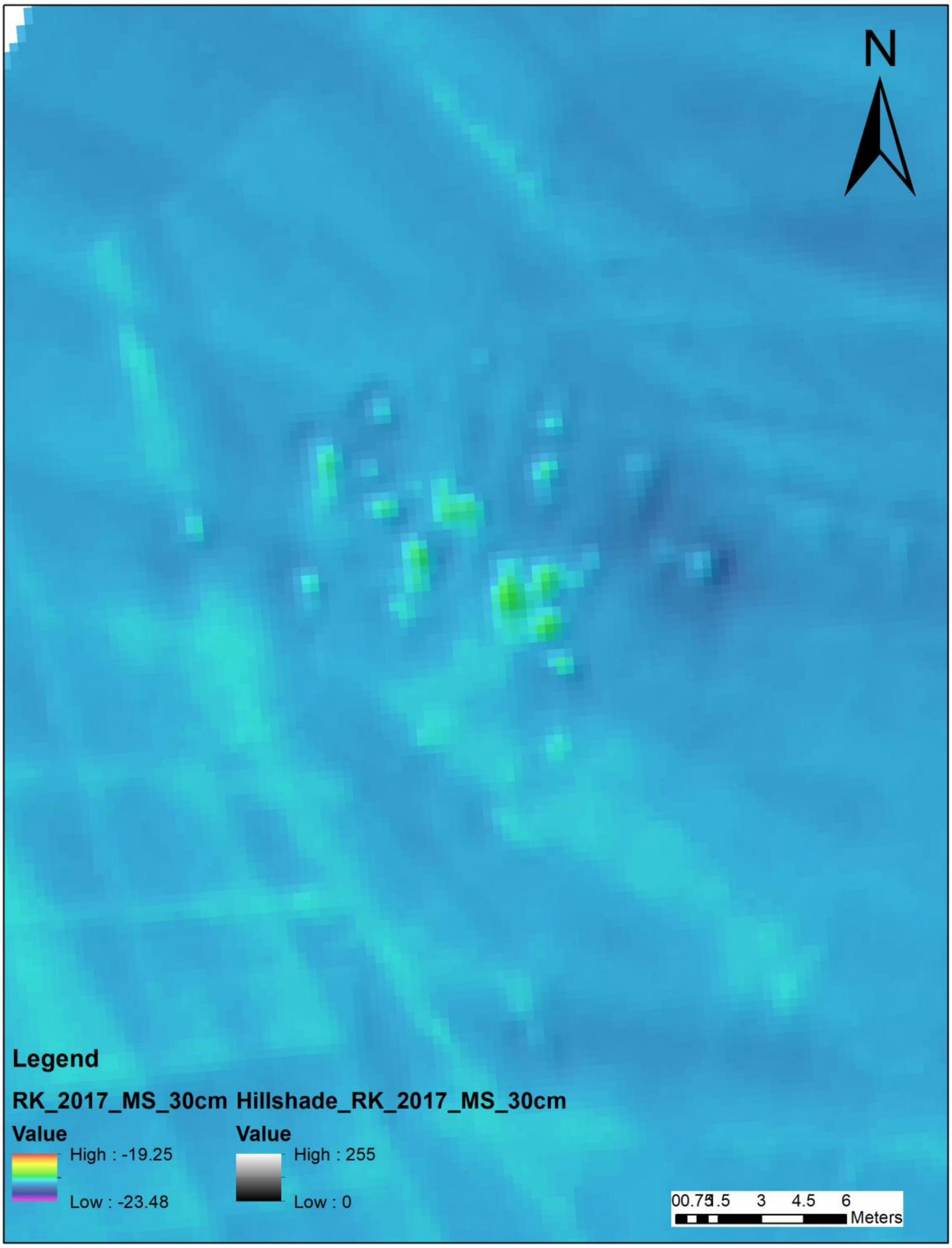


Figure 69. The figure shows the North Site MBES surveys of the *Rooswijk* site in 2017. The data was kindly provided by PAS. The data collection was carried out by MSDS Marine Ltd and Swathe Services, commissioned by HE and managed by PAS. The author of this thesis created the maps in ArcMap 10.5®.

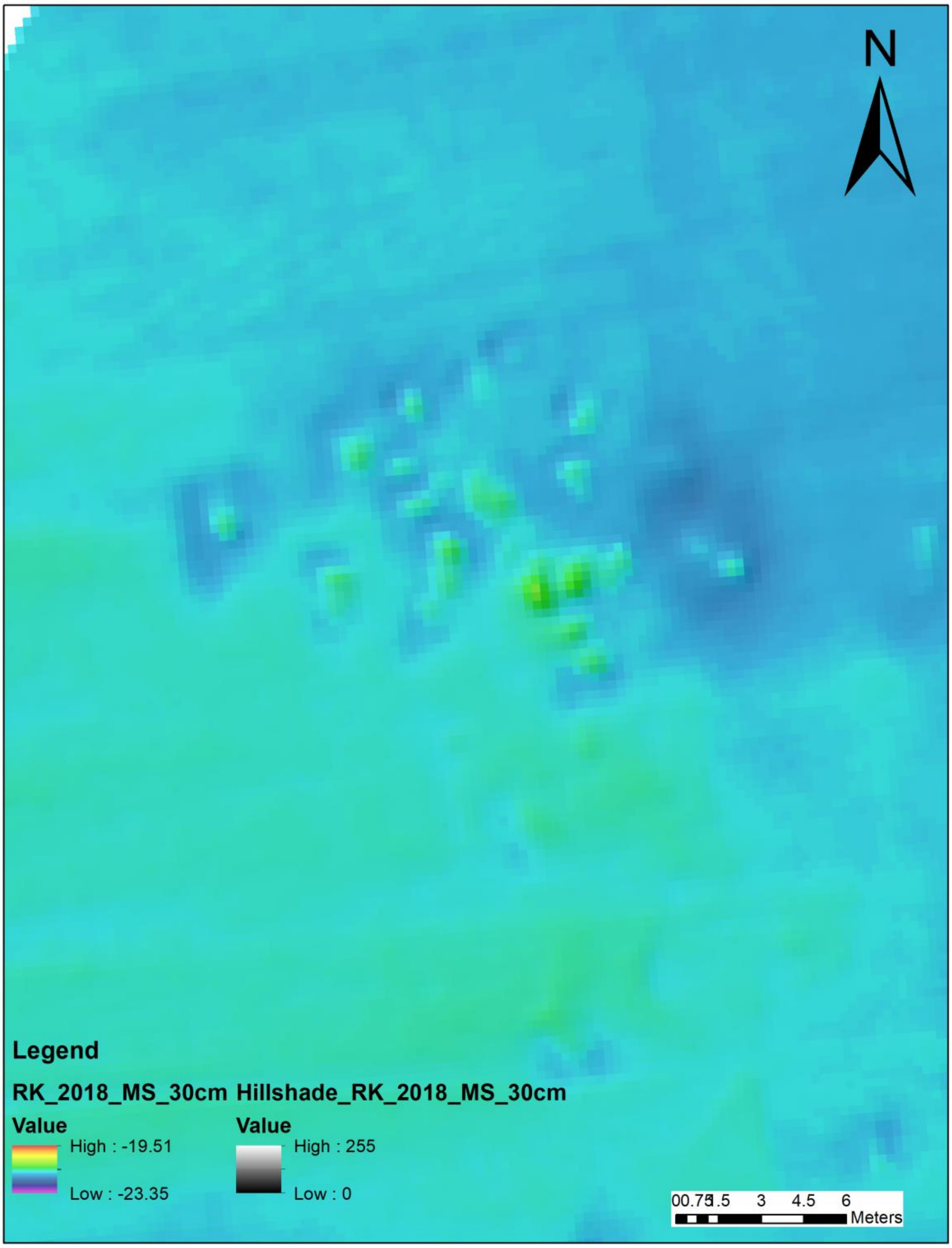


Figure 70. The figure shows the North Site MBES surveys of the *Rooswijk* site in 2018. The data was kindly provided by PAS. The data collection was carried out by MSDS Marine Ltd and Swathe Services, commissioned by HE and managed by PAS. The author of this thesis created the maps in ArcMap 10.5®.

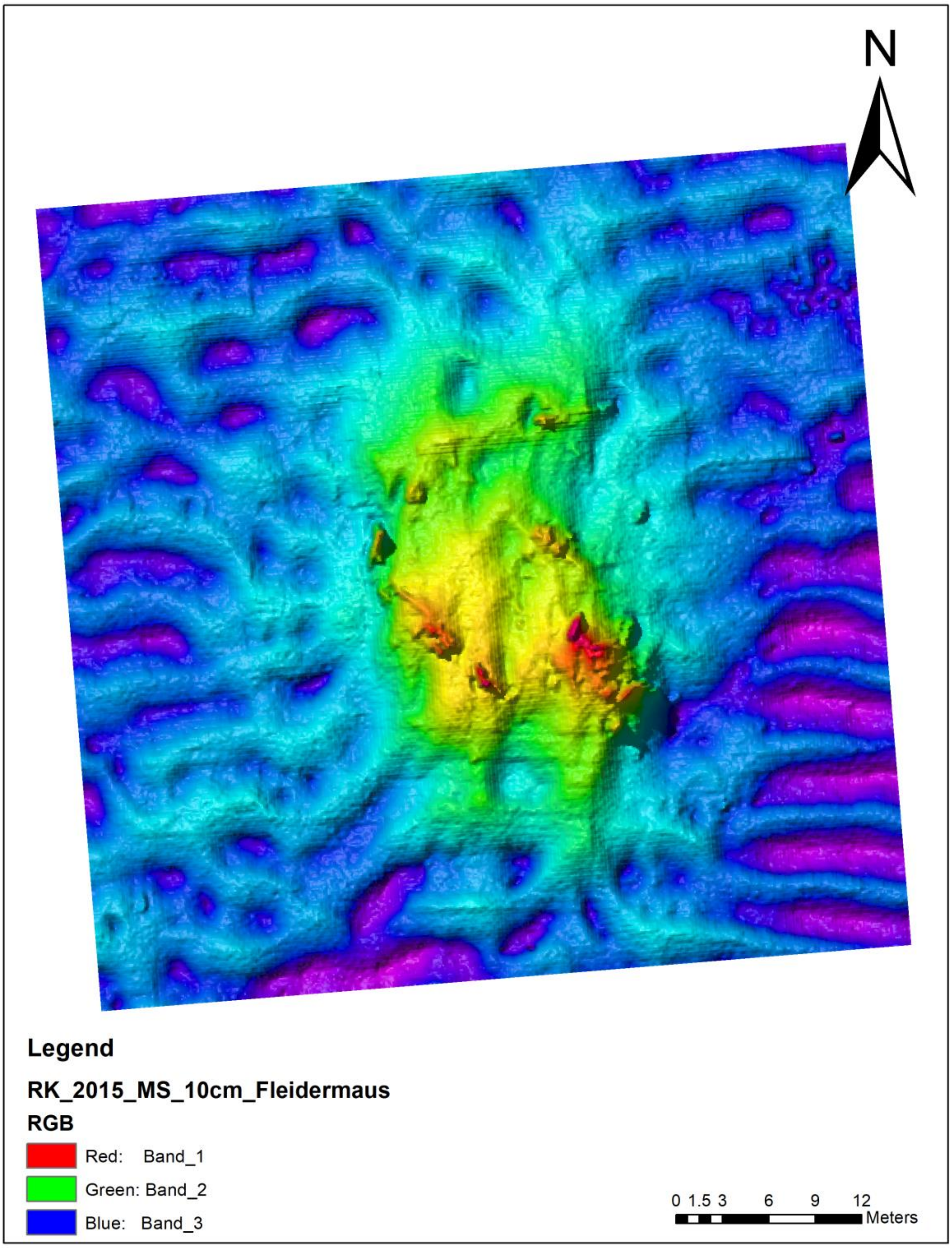


Figure 71. The figure shows the West Site MBES surveys of the *Rooswijk* site in 2015. The data collection was carried out by Swathe Services, commissioned by RCE and managed by Trendarch. The author of this thesis created the maps in ArcMap 10.5®. Processed with Fledermaus®.

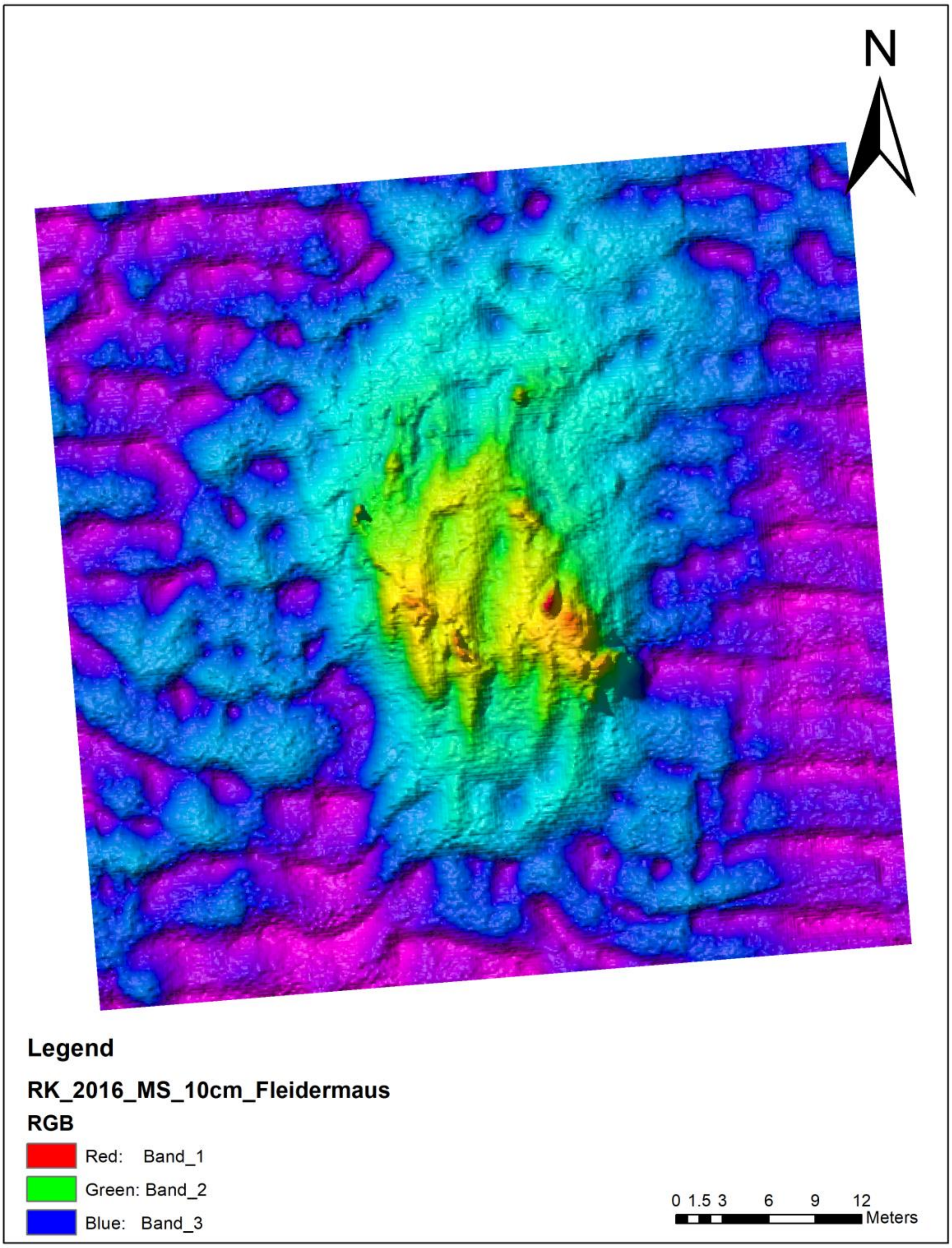


Figure 72. The figure shows the West Site MBES surveys of the *Rooswijk* site in 2016. The data collection was carried out by MSDS Marine Ltd and Swathe Services, commissioned by RCE. The author of this thesis created the maps in ArcMap 10.5®. Processed with Fledermaus ®

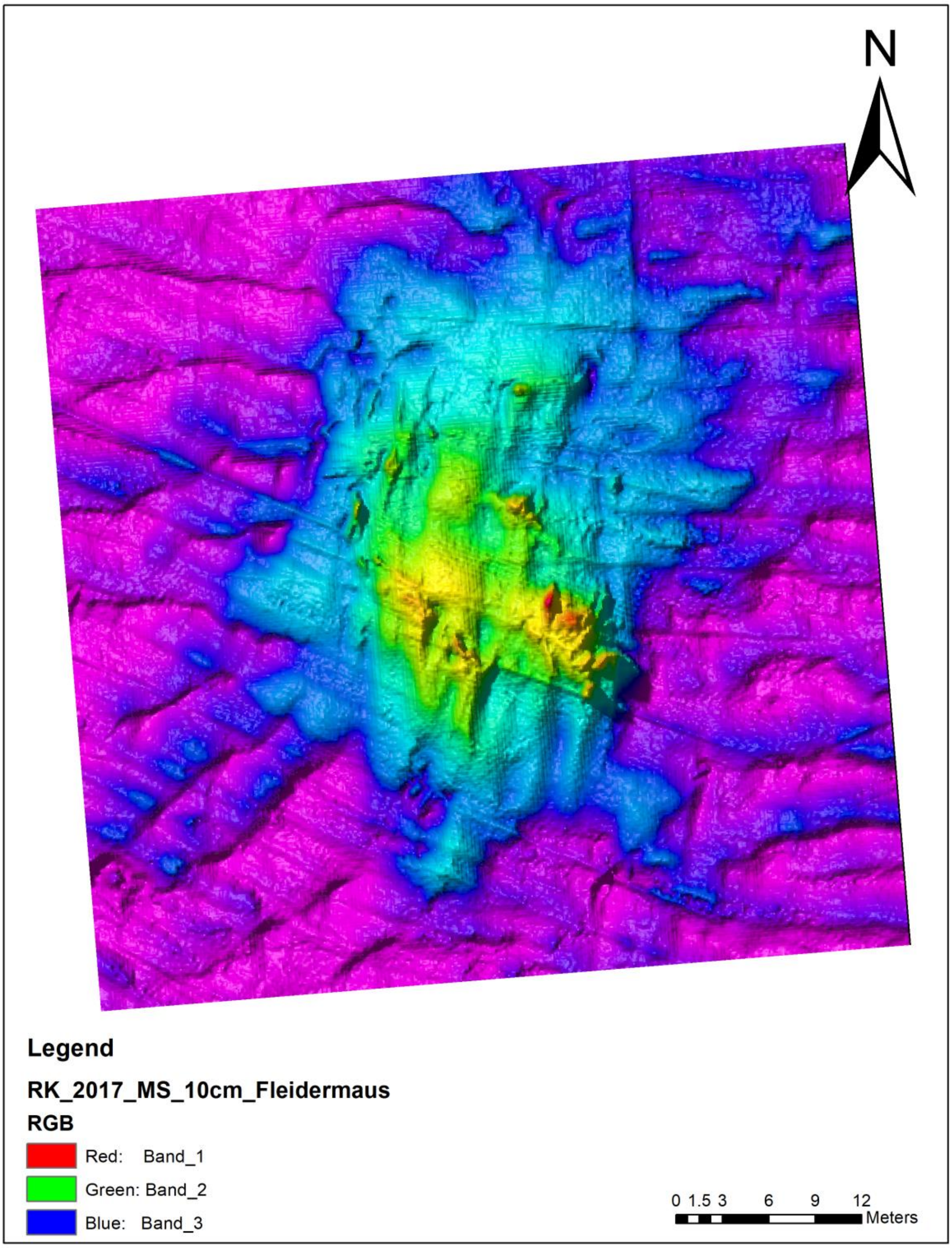


Figure 73. The figure shows the West Site MBES surveys of the *Rooswijk* site in 2017. The data was kindly provided by PAS. The data collection was carried out by MSDS Marine Ltd and Swathe Services, commissioned by HE and managed by PAS. The author of this thesis created the maps in ArcMap 10.5®. Processed with Fledermaus ®

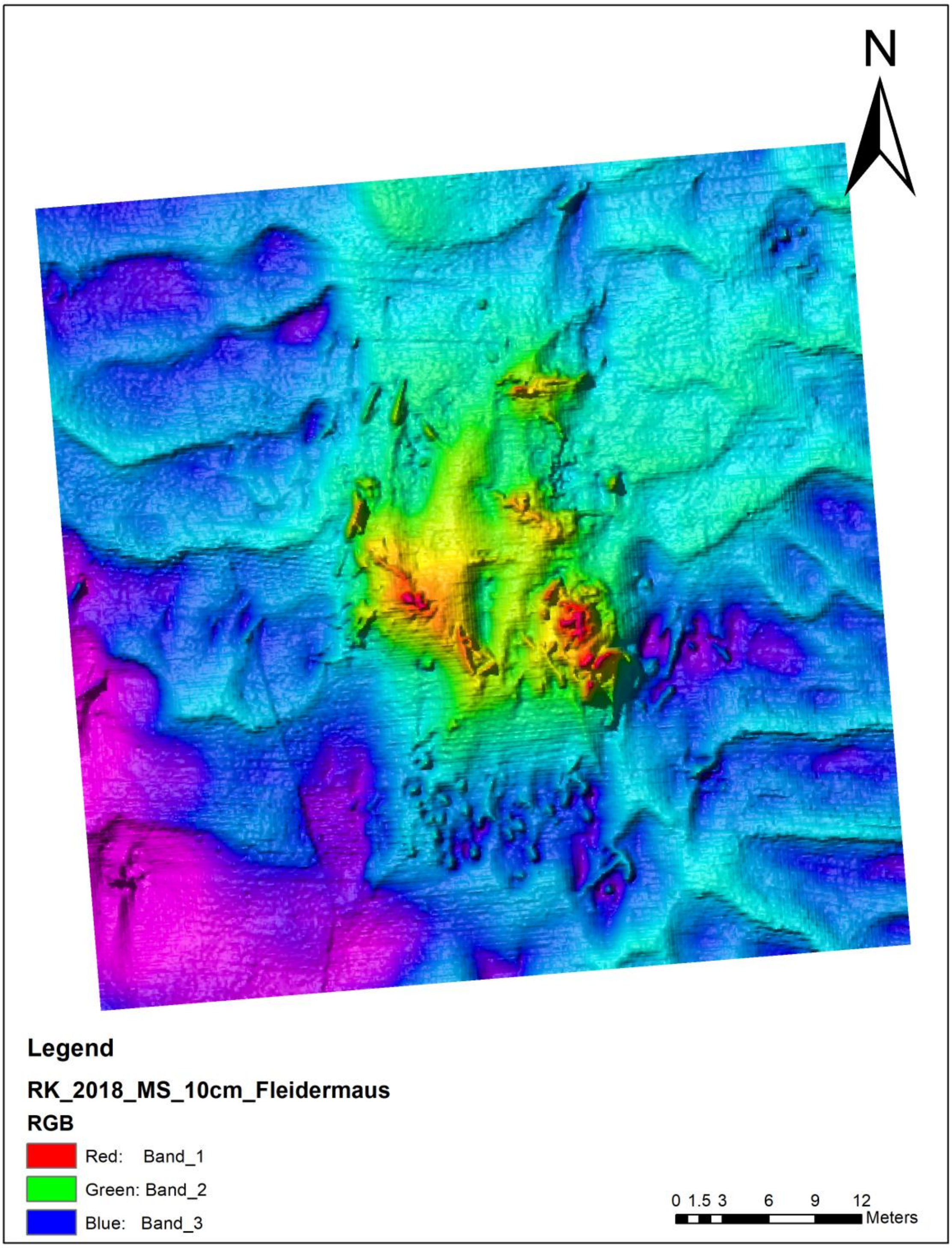


Figure 74. The figure shows the West Site MBES surveys of the *Rooswijk* site in 2018. The data was kindly provided by PAS. The data collection was carried out by MSDS Marine Ltd and Swathe Services, commissioned by HE and managed by PAS. The author of this thesis created the maps in ArcMap 10.5®. Processed with Fledermaus ®

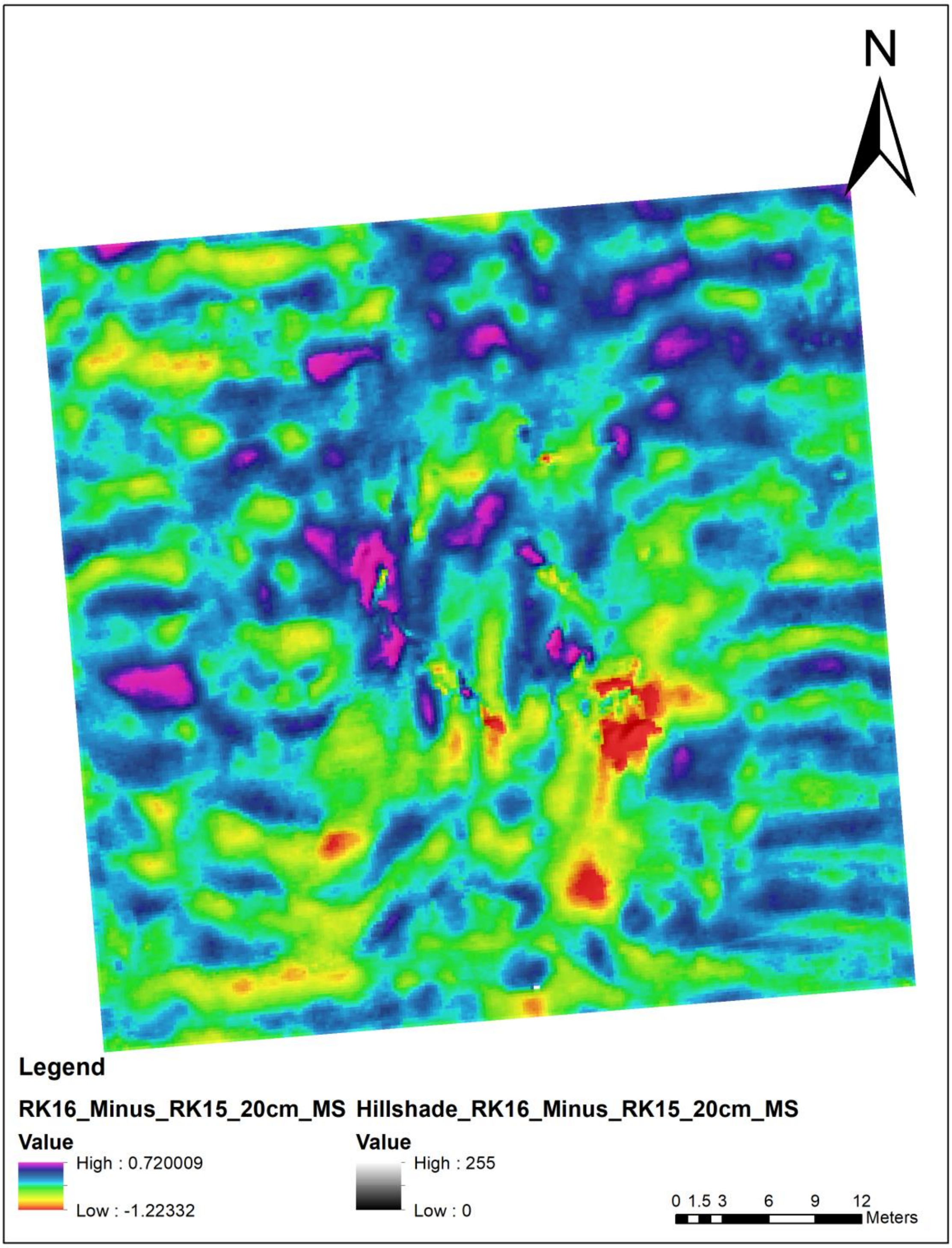


Figure 75. MBES time-series displayed on ArcMap 10.5®, showing sediment migration of the West site. A) 2015-2016. The survey was carried out at 700 kHz with an R2 Sonic 2024 system with a 10 cm resolution. The data was kindly provided by PAS. Swathe Services and MSDS Marine Ltd carried out the survey. The author of this thesis created the maps in ArcMap 10.5®.

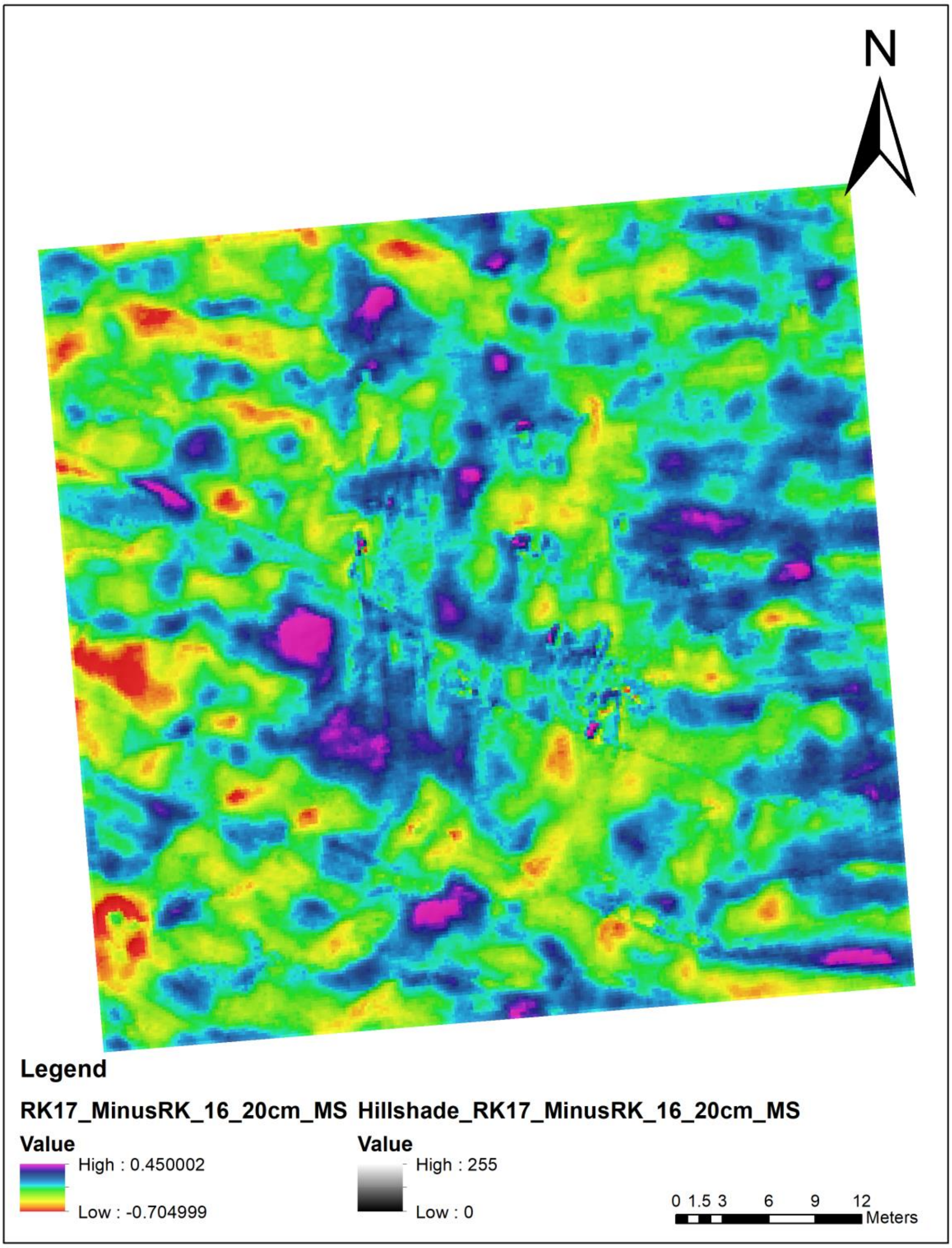


Figure 76. MBES time-series displayed on ArcMap 10.5®, showing sediment migration of the West site. 2016-2017. The survey was carried out at 700 kHz with an R2 Sonic 2024 system with a 10 cm resolution. The data was kindly provided by PAS. MSDS Marine Ltd carried out the survey. The author of this thesis created the maps in ArcMap 10.5®.

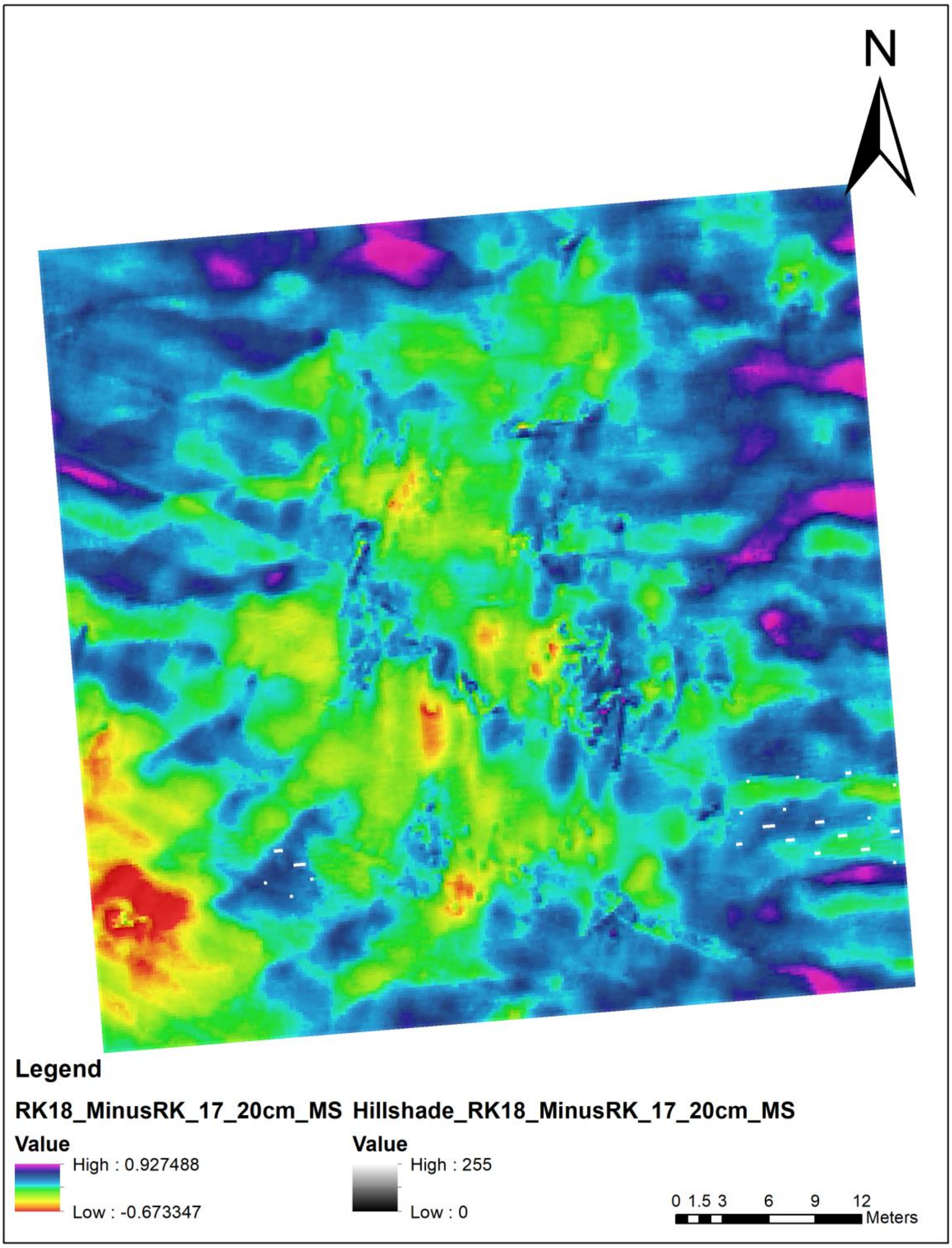


Figure 77. MBES time-series displayed on ArcMap 10.5®, showing sediment migration of the West site. 2017-2018. The survey was carried out at 700 kHz with an R2 Sonic 2024 system with a 10 cm resolution. The data was kindly provided by PAS. MSDS Marine Ltd carried out the survey. The author of this thesis created the maps in ArcMap 10.5®.

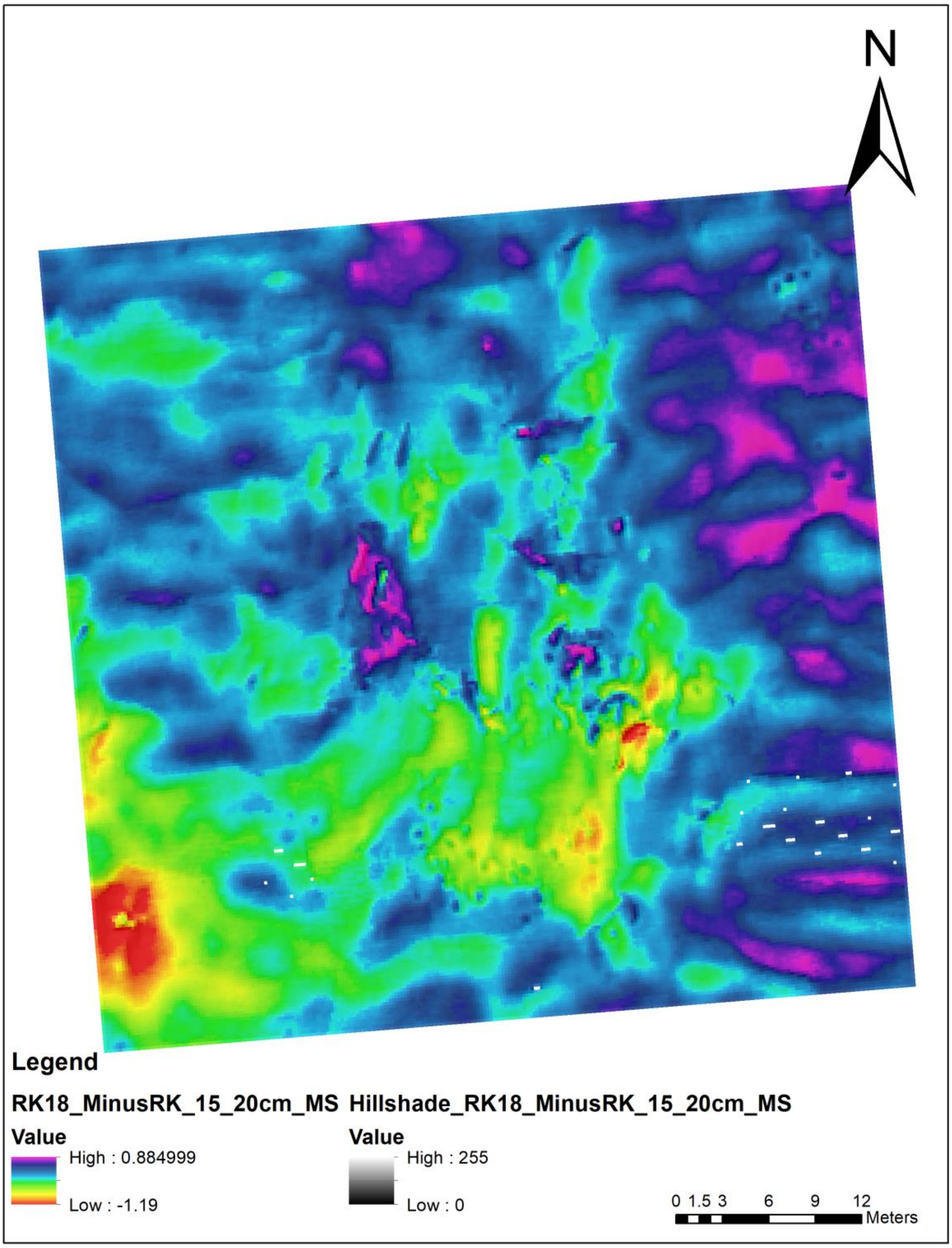


Figure 78. MBES time-series displayed on ArcMap 10.5®, showing sediment migration of the West site. 2015-2018. The survey was carried out at 700 kHz with an R2 Sonic 2024 system with a 10 cm resolution. The data was kindly provided by PAS. MSDS Marine Ltd carried out the survey. The author of this thesis created the maps in ArcMap 10.5®.

2.B.3 Photogrammetry. *Rooswijk* 1738-1740

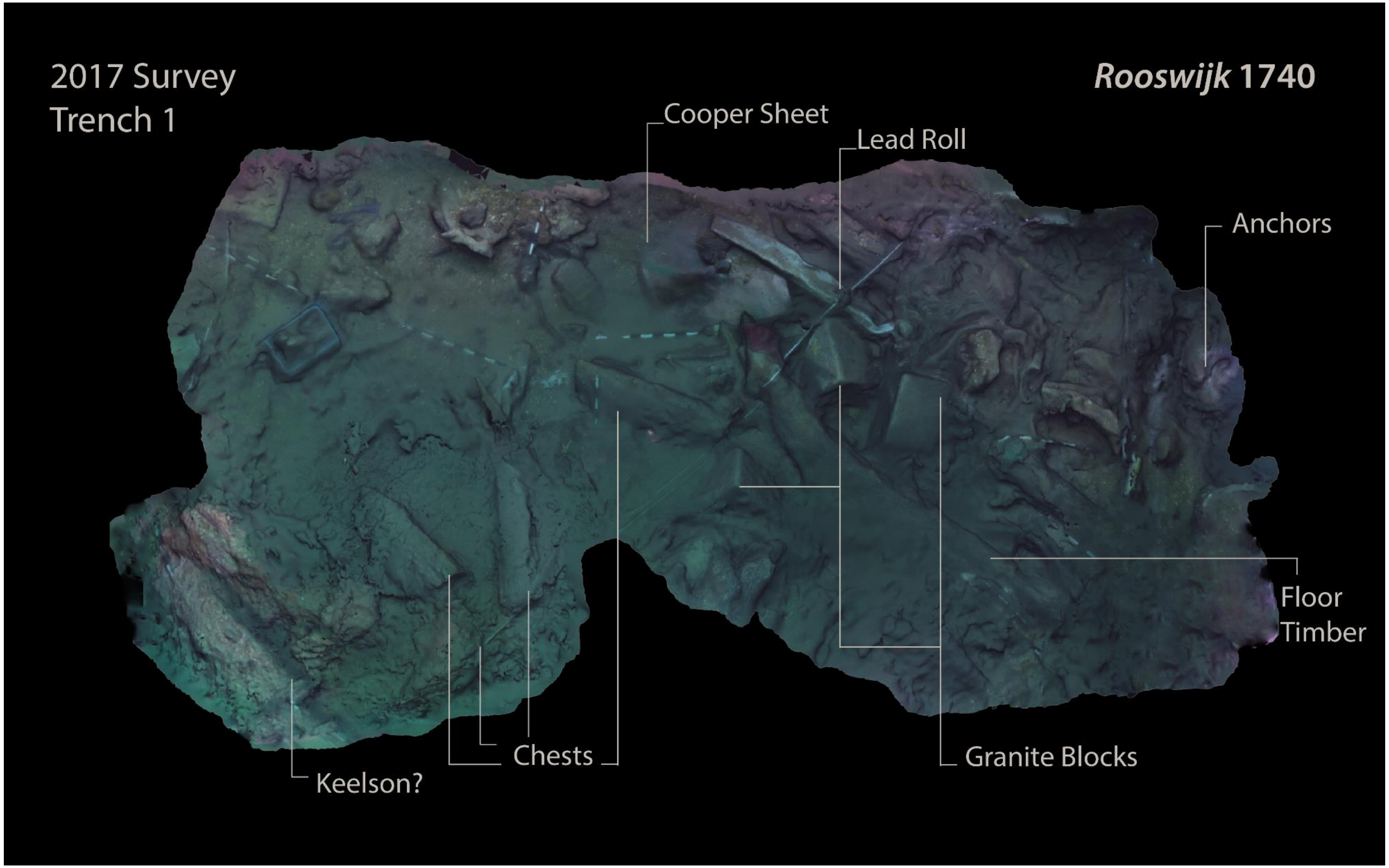


Figure 79. The author of this thesis created the photogrammetry survey and processed it on Agisoft Metashape Pro v1.5 ®. The image was rendered in 3dsMax®.

Figure 80. The figure a breech block used to load a bronze gun. The author of this thesis recorded the artefact and rendered the images in 3dsMax®. The images are used with the kind permission of the *Rooswijk* 1740 project.

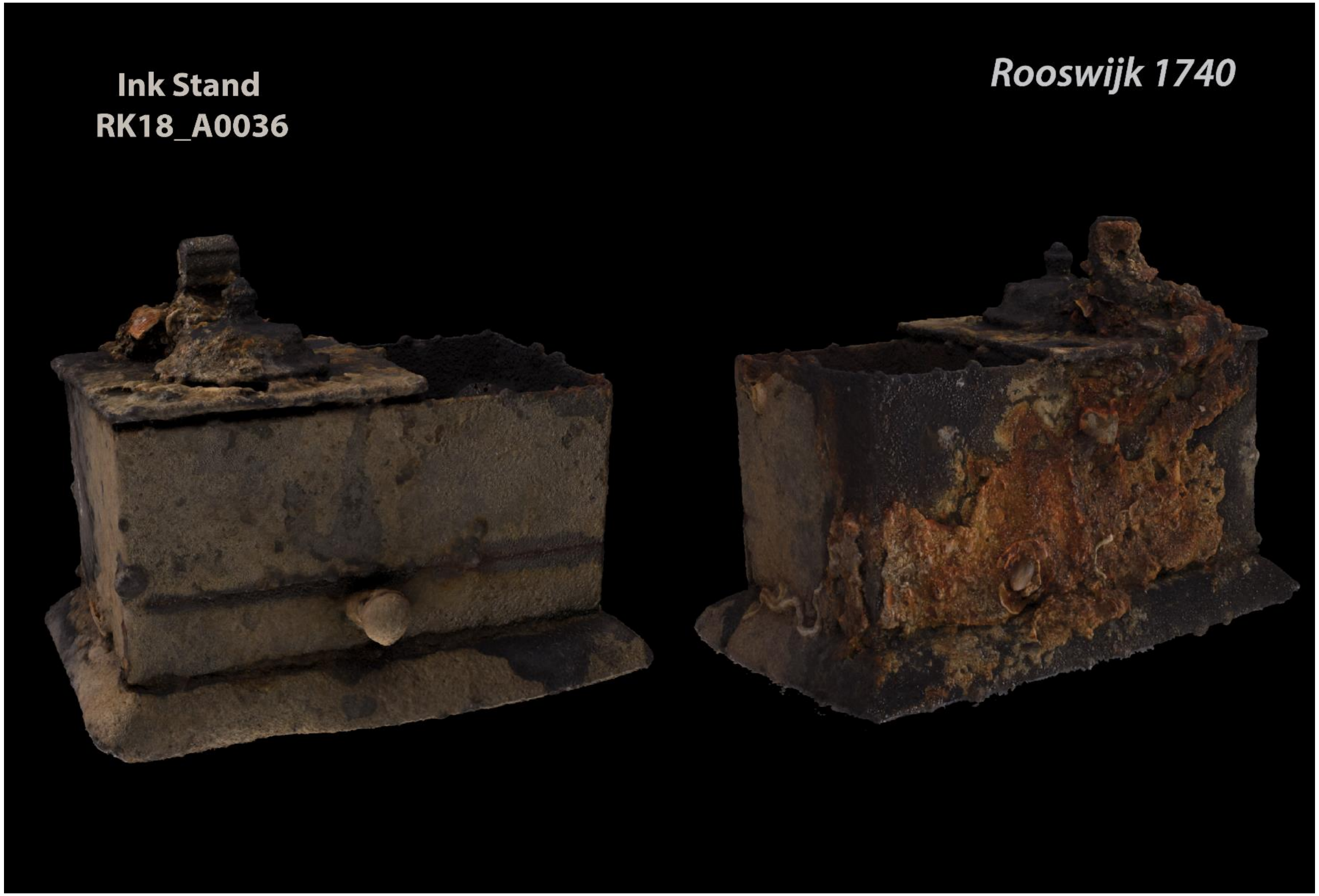


Figure 81. The figure shows an inkstand. The author of this thesis recorded the artefact and rendered the images in 3dsMax®. The images are used with the kind permission of the *Rooswijk* 1740 project.

Figure 82. The figure shows a pewter tankard. The author of this thesis recorded the artefact and rendered the images in 3dsMax®. The images are used with the kind permission of the *Rooswijk* 1740 project.

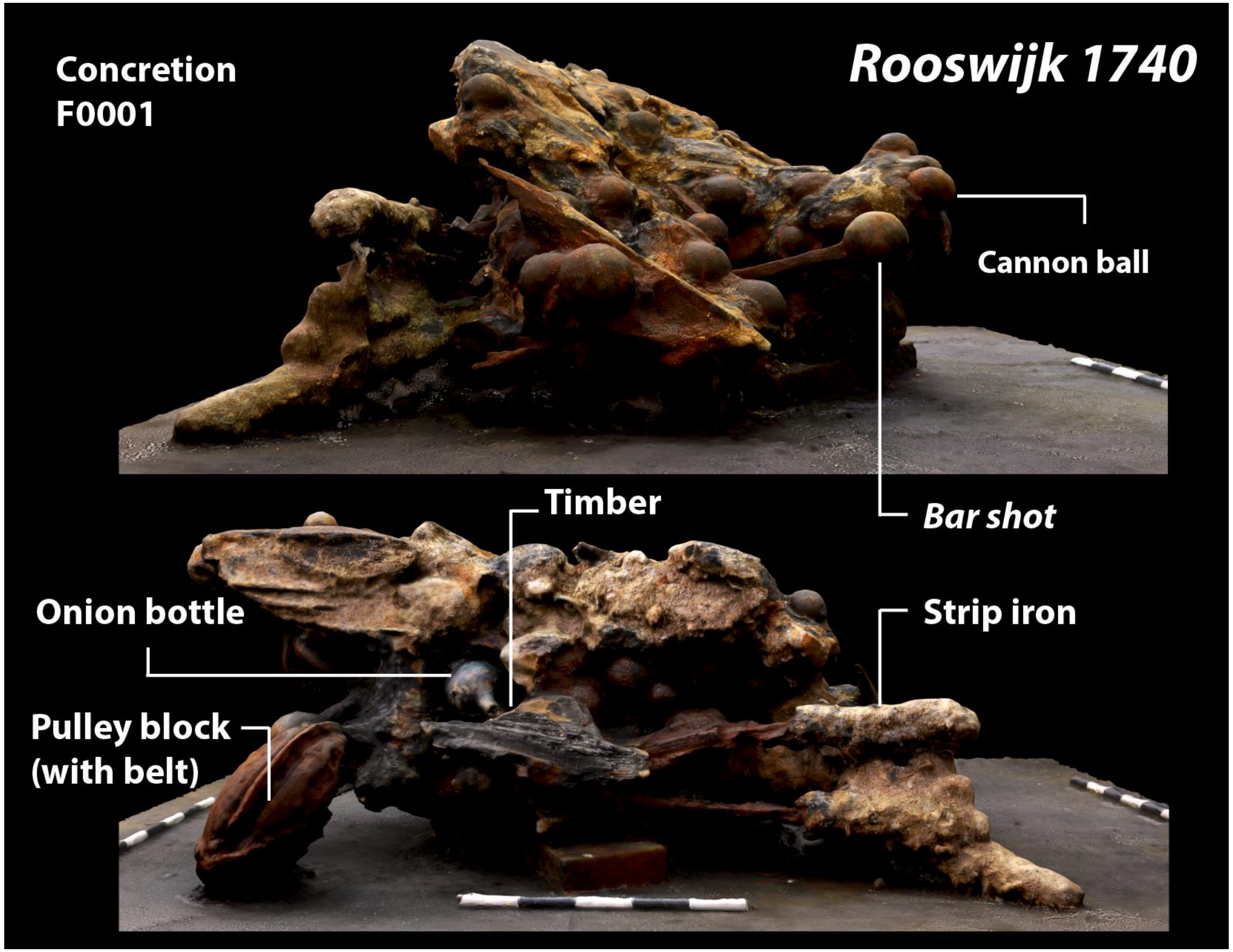


Figure 83. The figure shows a large concretion recovered from Trench 1 that was disarticulated into individual artefacts. The author of this thesis recorded the artefact and rendered the images in 3dsMax®. The images are used with the kind permission of the *Rooswijk* 1740 project.

2.B.4 Coins. *Rooswijk* 1738-1740

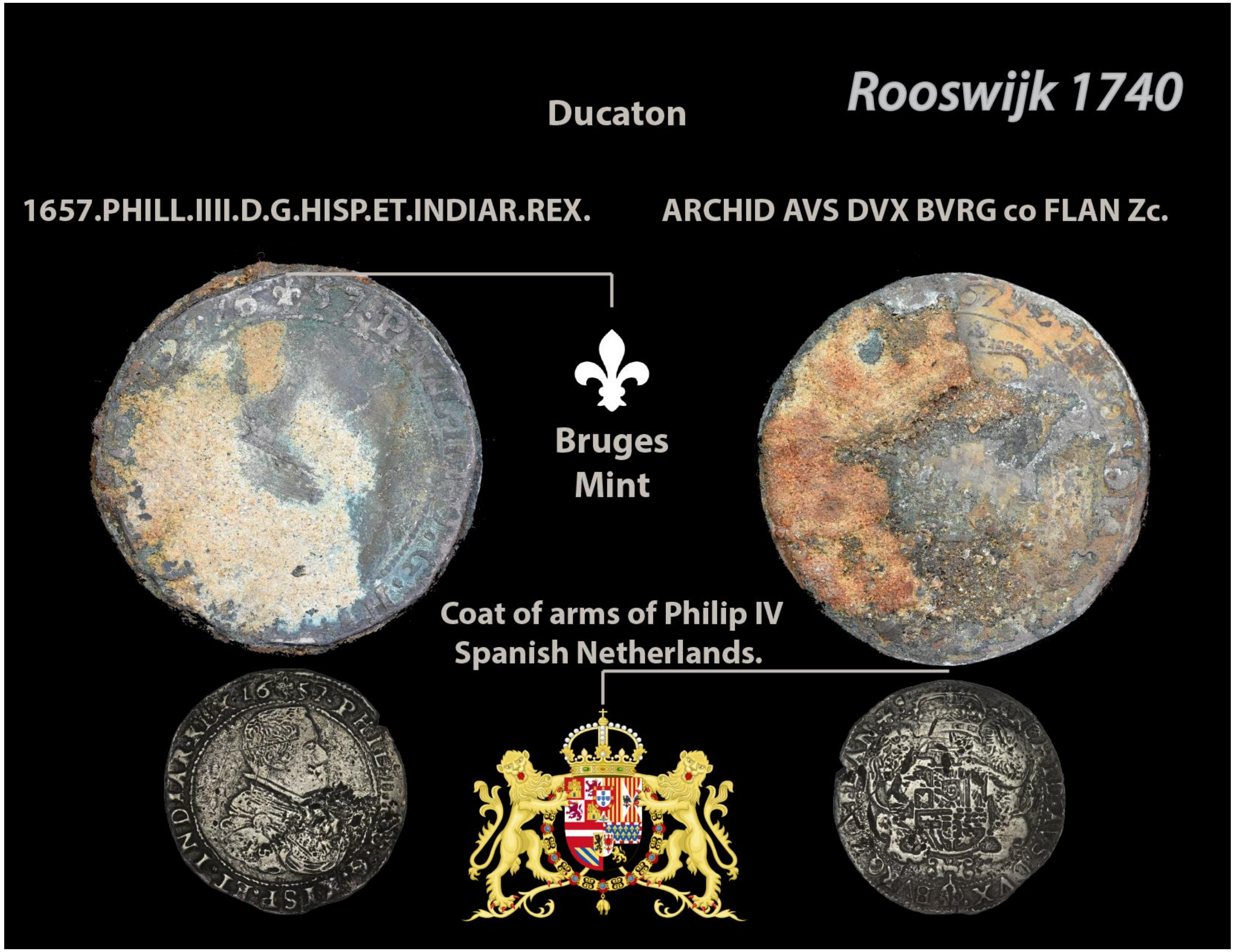


Figure 84. The figure shows a Dutch Ducaton, found on *Rooswijk*2017, dated to 1657. The obverse had a portrait of Phillip IV, King of Spain and the Indies. The reverse has a crown shield with the Spanish kingdom, including Flanders. The mintmark is from Bruges. The author of this thesis created the figure.

Figure 85. The figure shows a several Dutch Ducatons stacked, left as they were stored, they found on *Rooswijk*. The Coin on the top is date to 1673. . The obverse has a portrait of Charles II, King of Spain and the Indies. The reverse had a crown shield with the Spanish kingdom, including Flanders. The mintmark is from Antwerp. The author of this thesis created the figure.

Figure 86. The figure shows a Dutch Ducaton found on *Rooswijk*. The Coin on the top is date to 1637. The obverse had a portrait of Phillip IV, King of Spain and the Indies. The reverse has a crown shield with the Spanish kingdom, including Flanders. The mintmark is from Antrwerp. The author of this thesis created the figure.

Figure 87. The figure shows a Dutch Stuiver of 6, "Rijderschelling" found on *Rooswijk*. No specific date could be from 1685 to 1691. The obverse shows a Rider (*Rijder*). The reverse has a double-headed eagle. No mintmark, but these coins are from Nijmegen. The author of this thesis created the figure.

Figure 88. The figure shows a Spanish Klippe 8 (Clipper) or *recortada*, found on *Rooswijk*. No specific date could be from 1733-4. The obverse shows a cross of Jerusalem with the kingdoms of Castile and Leon. The reverse shows Phillips V coats of arms. The mintmark is from Mexico City. The assayer mark is MF. The author of this thesis created the figure.

Figure 89. The figure shows a Spanish piece of 4 (Cob) or *macuquina*, found on *Rooswijk*. No specific date could be from 1700-1746. The obverse shows the cross of Jerusalem with the kingdoms of Castile and Leon. The reverse shows Phillip V coat of arms. The mintmark is from Mexico City. The author of this thesis created the figure.

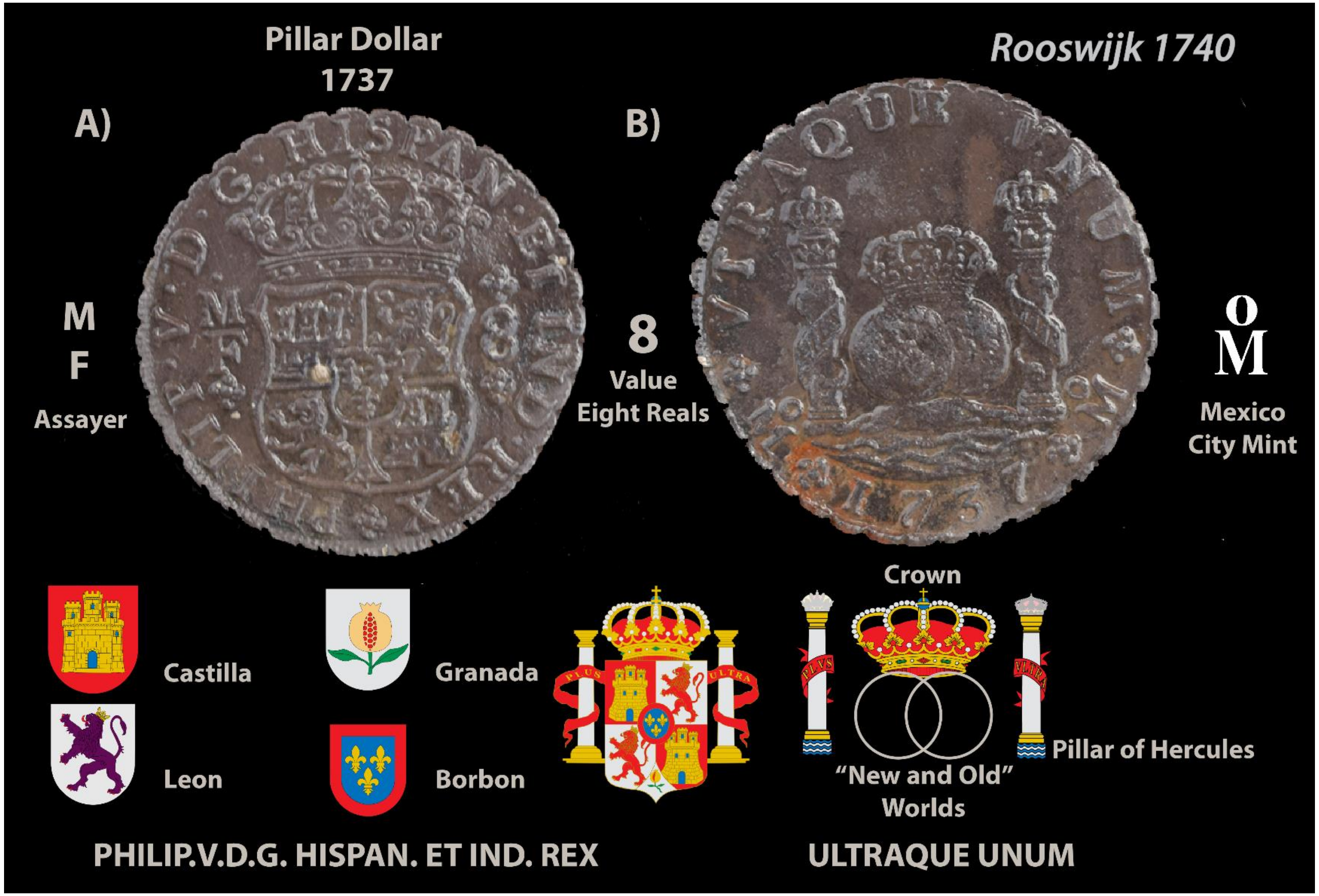


Figure 90. The figure shows a Spanish Pillar Dollar 8 (*columnaria, peso, real de ocho*), found on *Rooswijk*. The date is from 1737. The obverse shows a Bourbon Phillip V coat of arms the kingdoms of Castile and Leon. The reverse shows the Pillars of Hercules and both hemispheres (old and new world). The mintmark is from Mexico City. The assayer is MF. The author of this thesis created the figure.

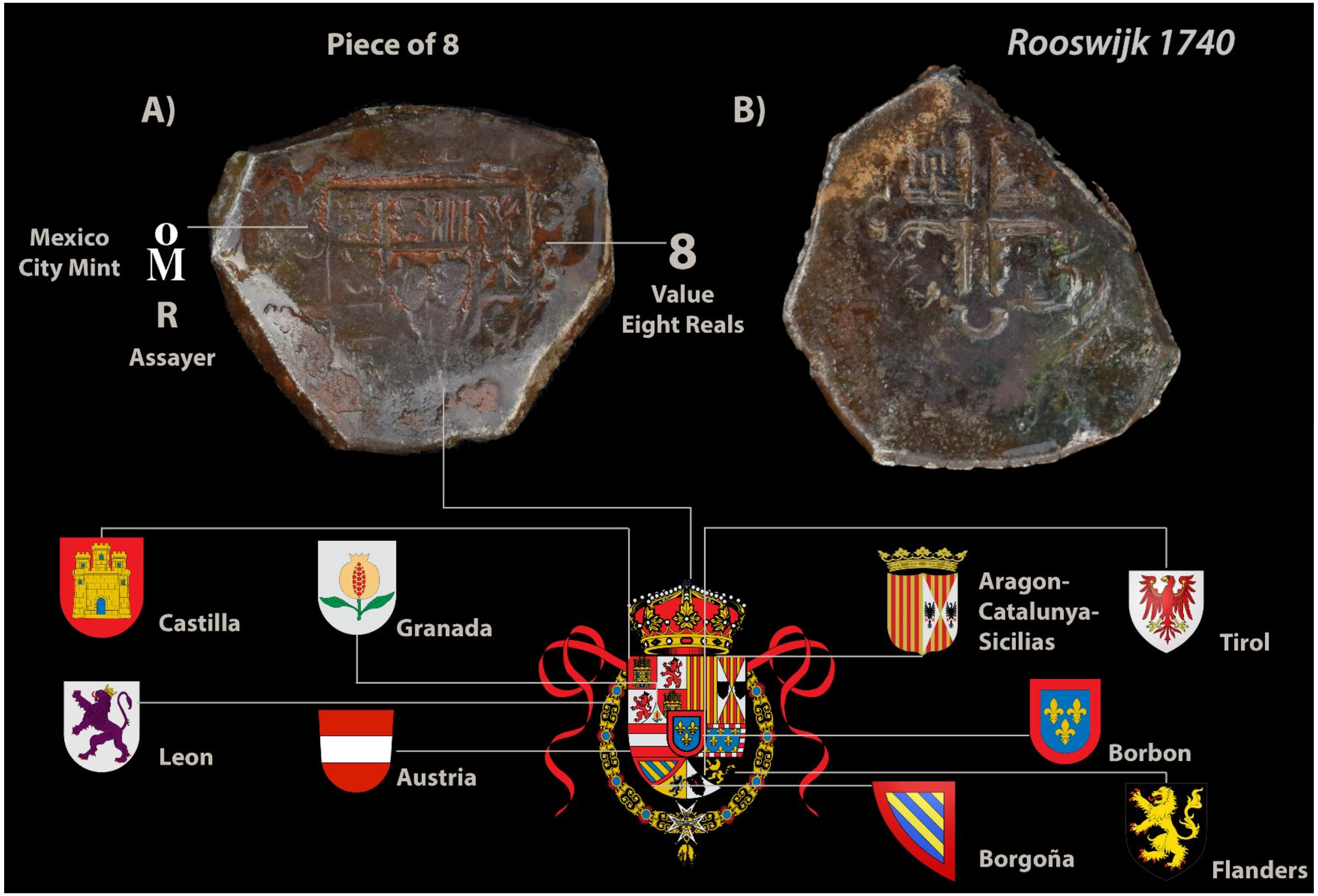


Figure 91. The figure shows a Spanish piece of 8 (*macuquina, real de ocho*), found on *Rooswijk*. The date is uncertain but ranges between 1700-1734. The obverse shows a Bourbon Phillip V. The reverse shows the cross of Jerusalem with the kingdoms of Castile and Leon. The mintmark is from Mexico City. The assayer is MR?. The author of this thesis created the figure.

2.B.5 Artefacts GIS. *Rooswijk* 1738-1740.

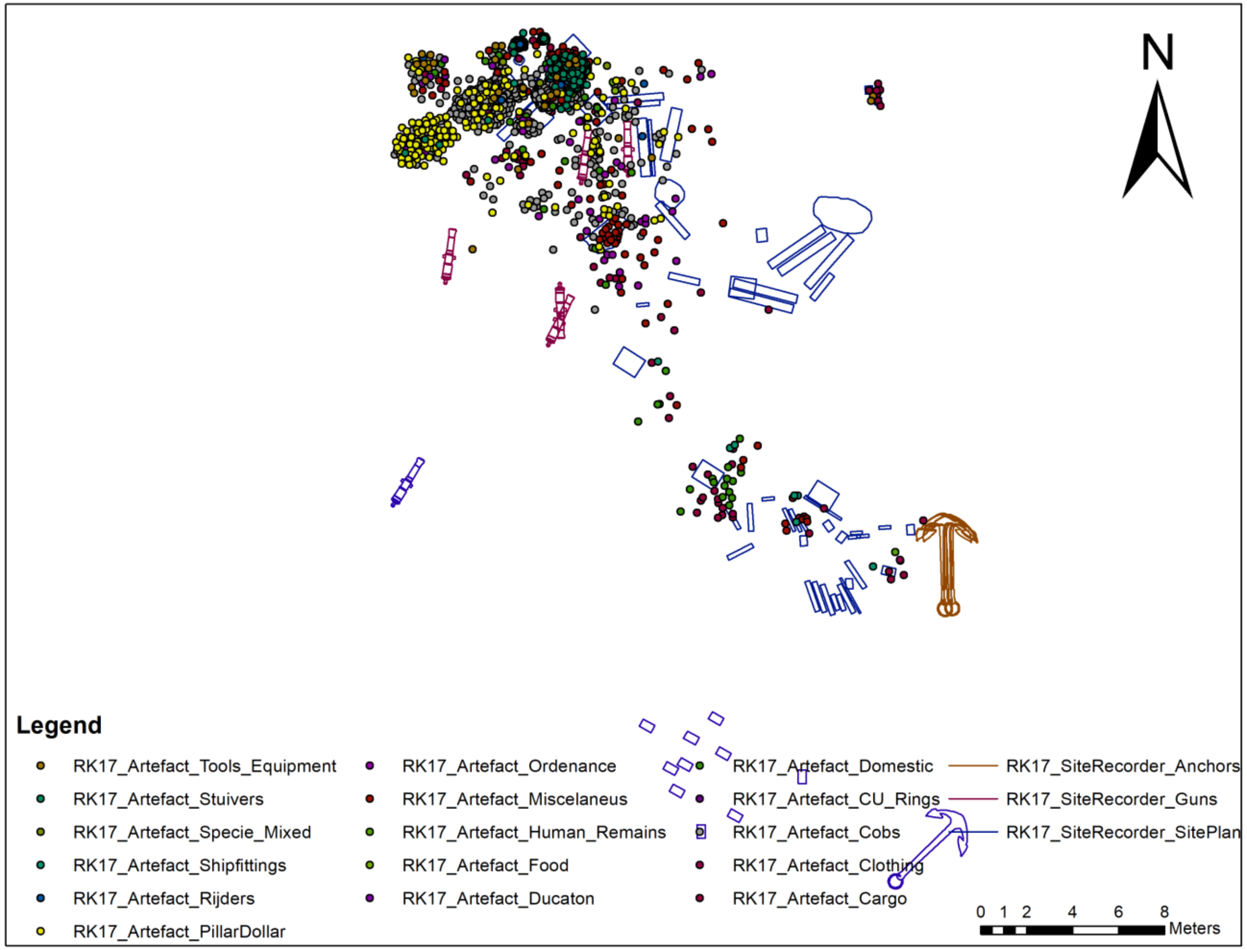


Figure 92. The figure shows the artefact distribution on the *Rooswijk*. The maps of artefact distribution where made with Site Recorder 4® and converted into Arc Map 10.5®. The author of this thesis created an image in ArcMap 10.5®.

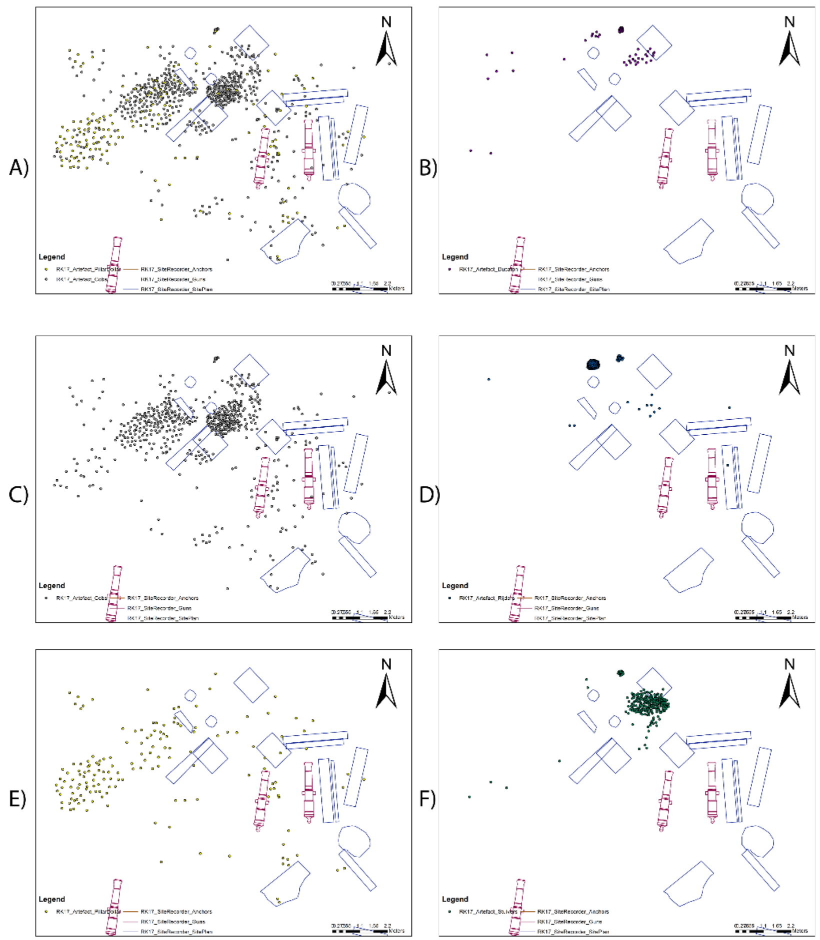


Figure 93. The figure shows specie distribution on the *Rooswijk*made with Site Recorder 4® and converted into Arc Map 10.5®.

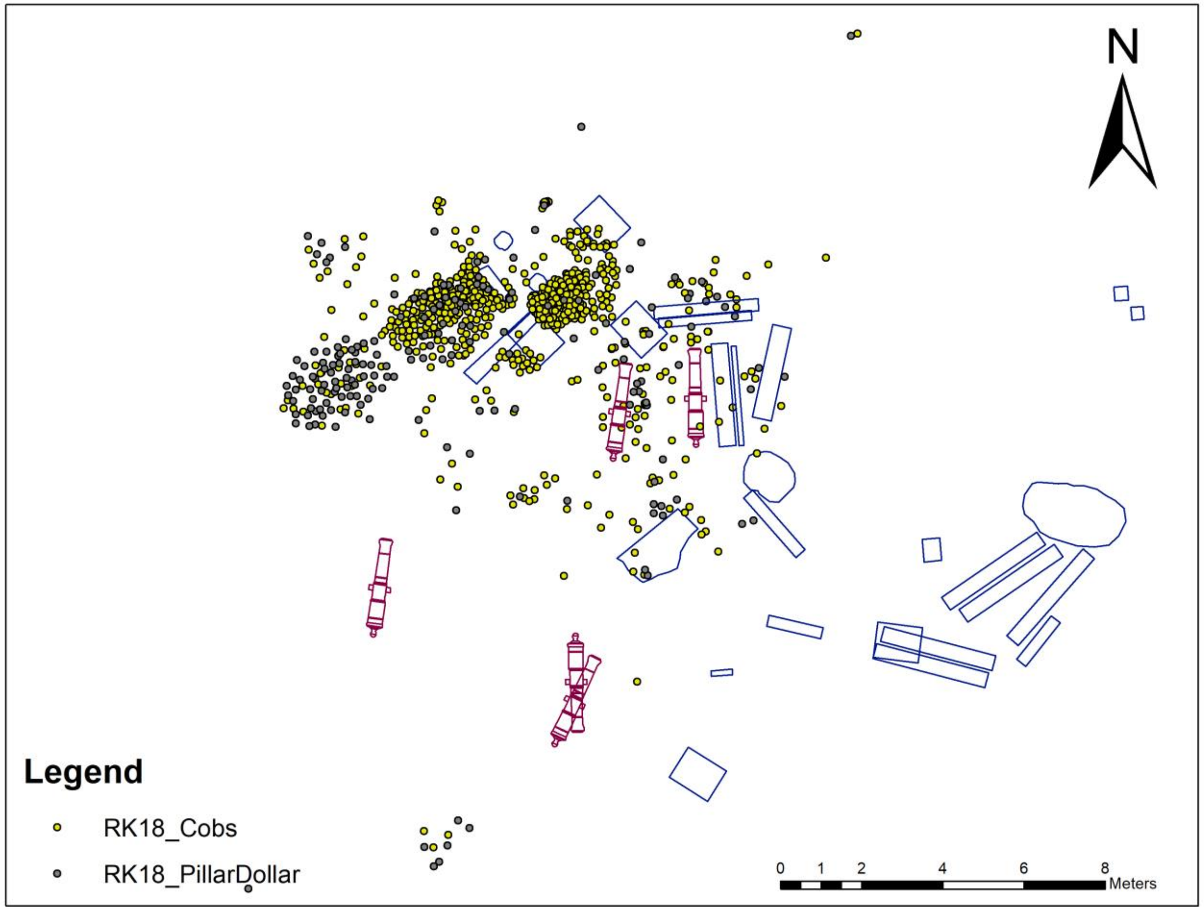


Figure 94. The figure shows the Spanish specie (pillar dollar and cobs) distribution on the *Rooswijk*. The maps of artefact distribution where made with Site Recorder 4® and converted into Arc Map 10.5®. The author of this thesis created an image in ArcMap 10.5®.

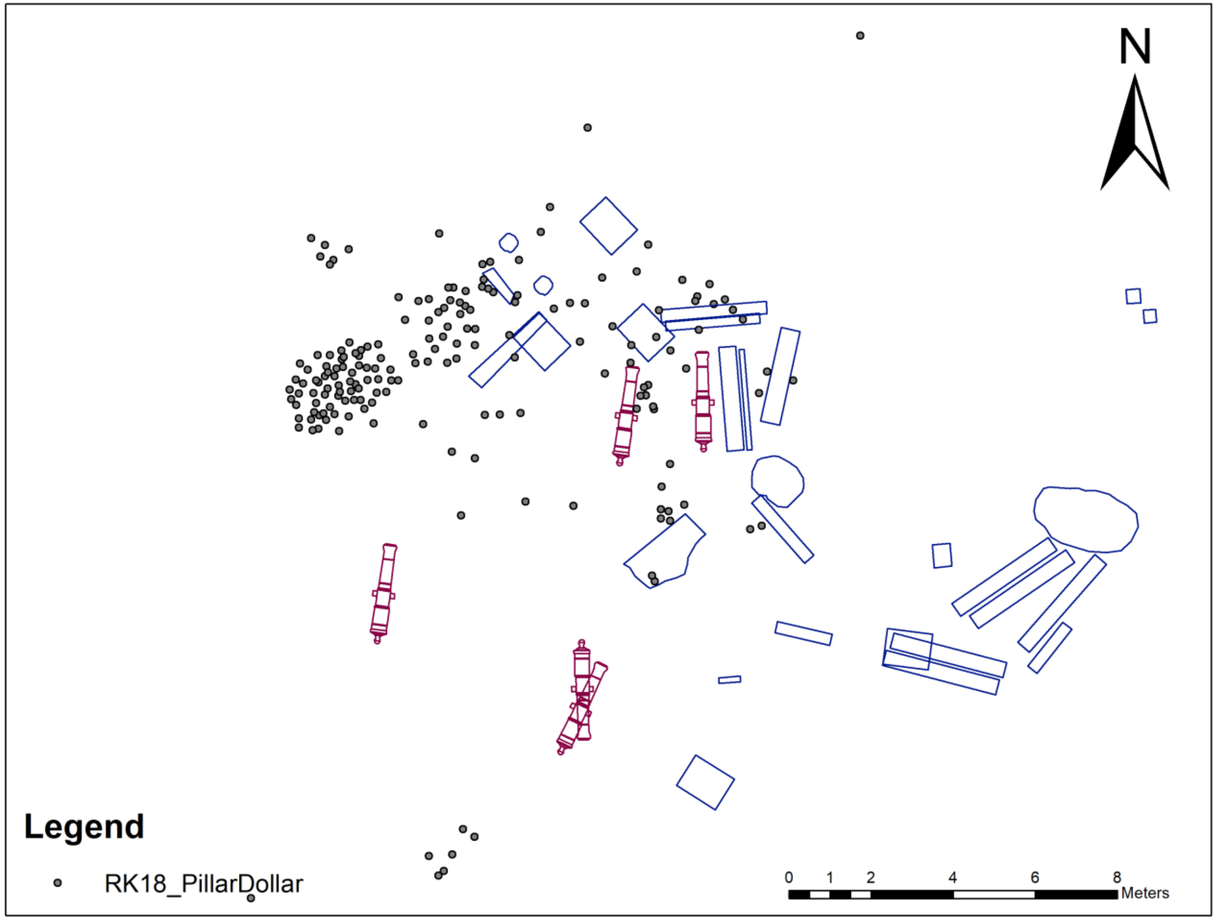


Figure 95. The figure shows the Pillar Dollar distribution on the *Rooswijk*. The maps of artefact distribution where made with Site Recorder 4® and converted into Arc Map 10.5®. The author of this thesis created an image in ArcMap 10.5®.

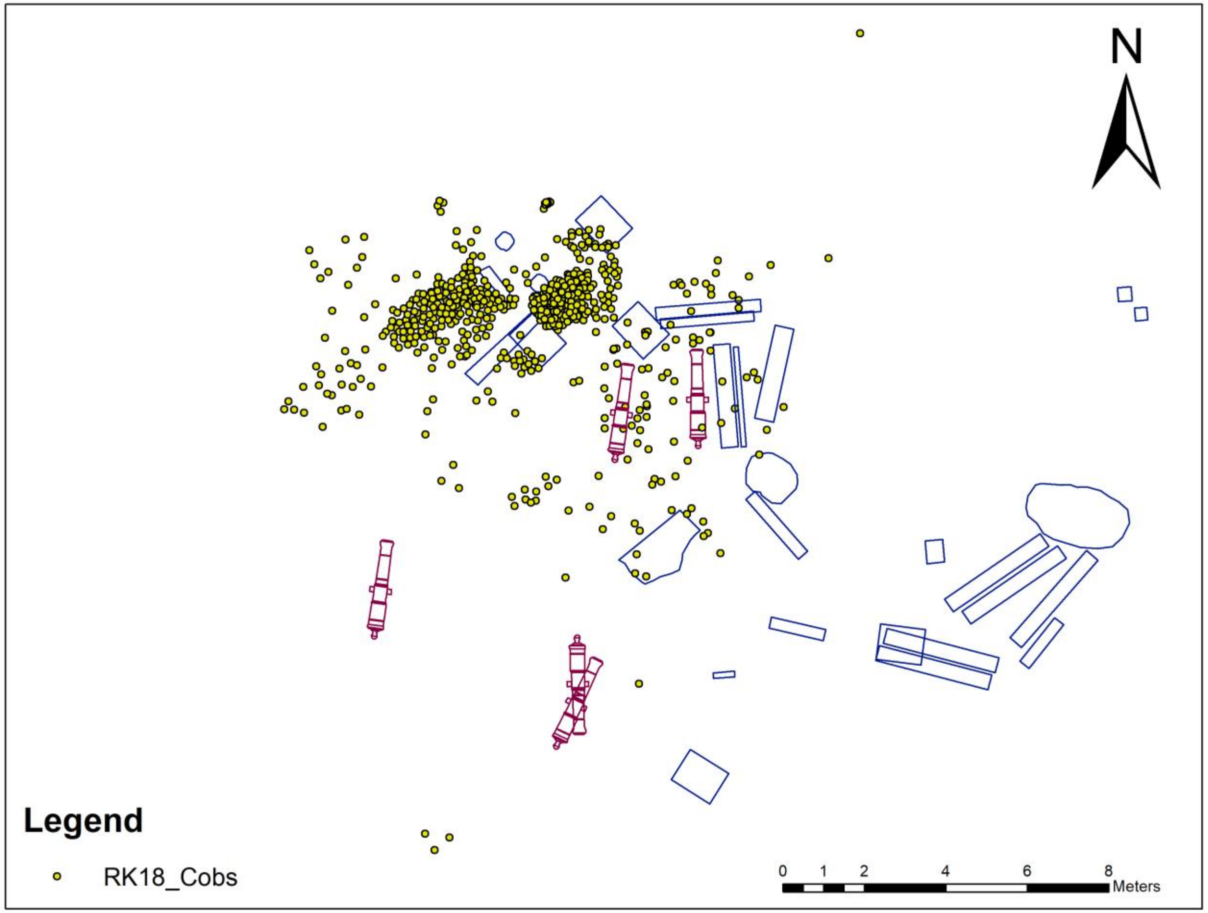


Figure 96. The figure shows the Cobs distribution on the *Rooswijk*. The maps of artefact distribution where made with Site Recorder 4® and converted into Arc Map 10.5®. The author of this thesis created an image in ArcMap 10.5®.

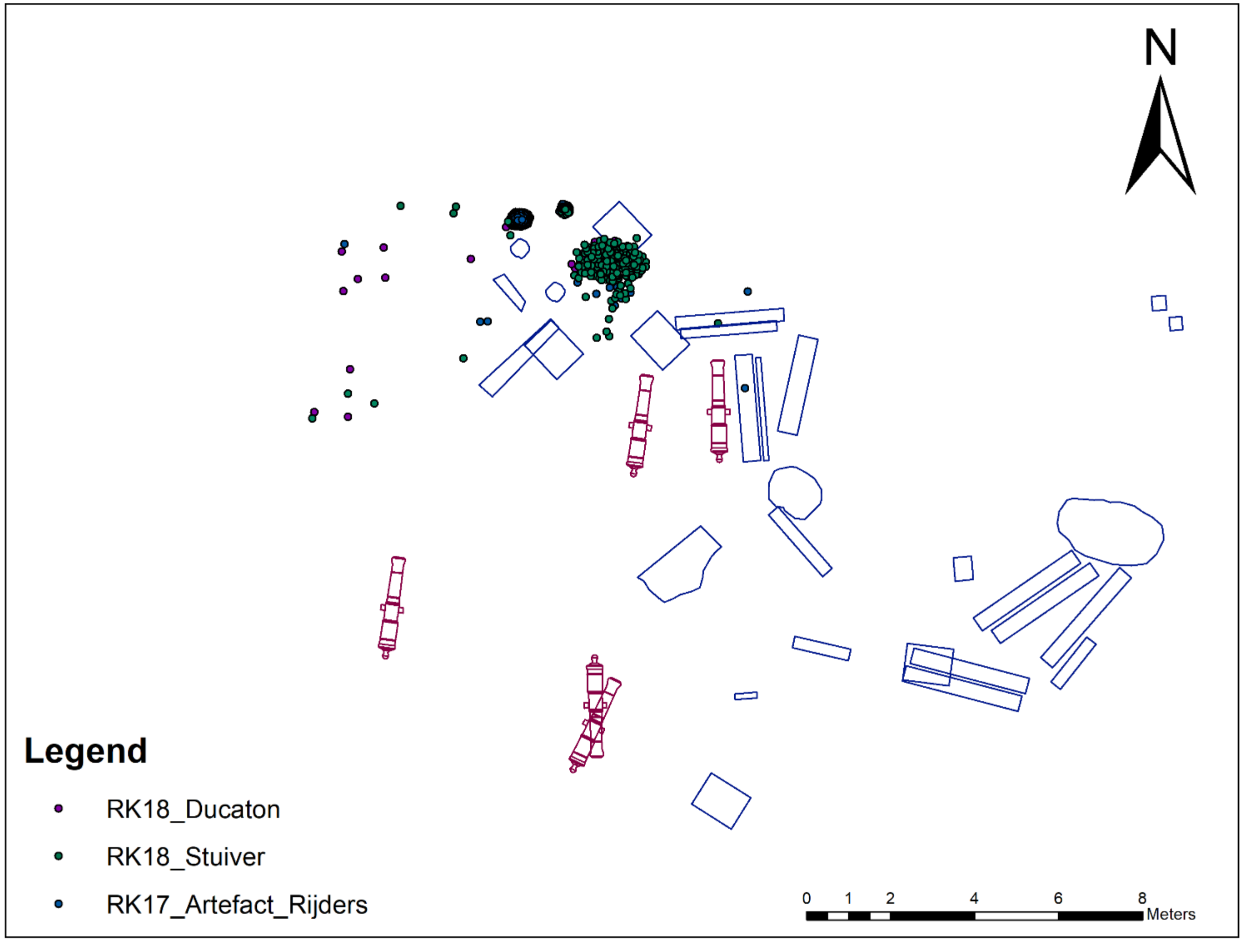


Figure 97. The figure shows the Dutch specie (Ducaton, Rijder, and Stuivers) distribution on the *Rooswijk*. The maps of artefact distribution where made with Site Recorder 4® and converted into Arc Map 10.5®. The author of this thesis created an image in ArcMap 10.5®.

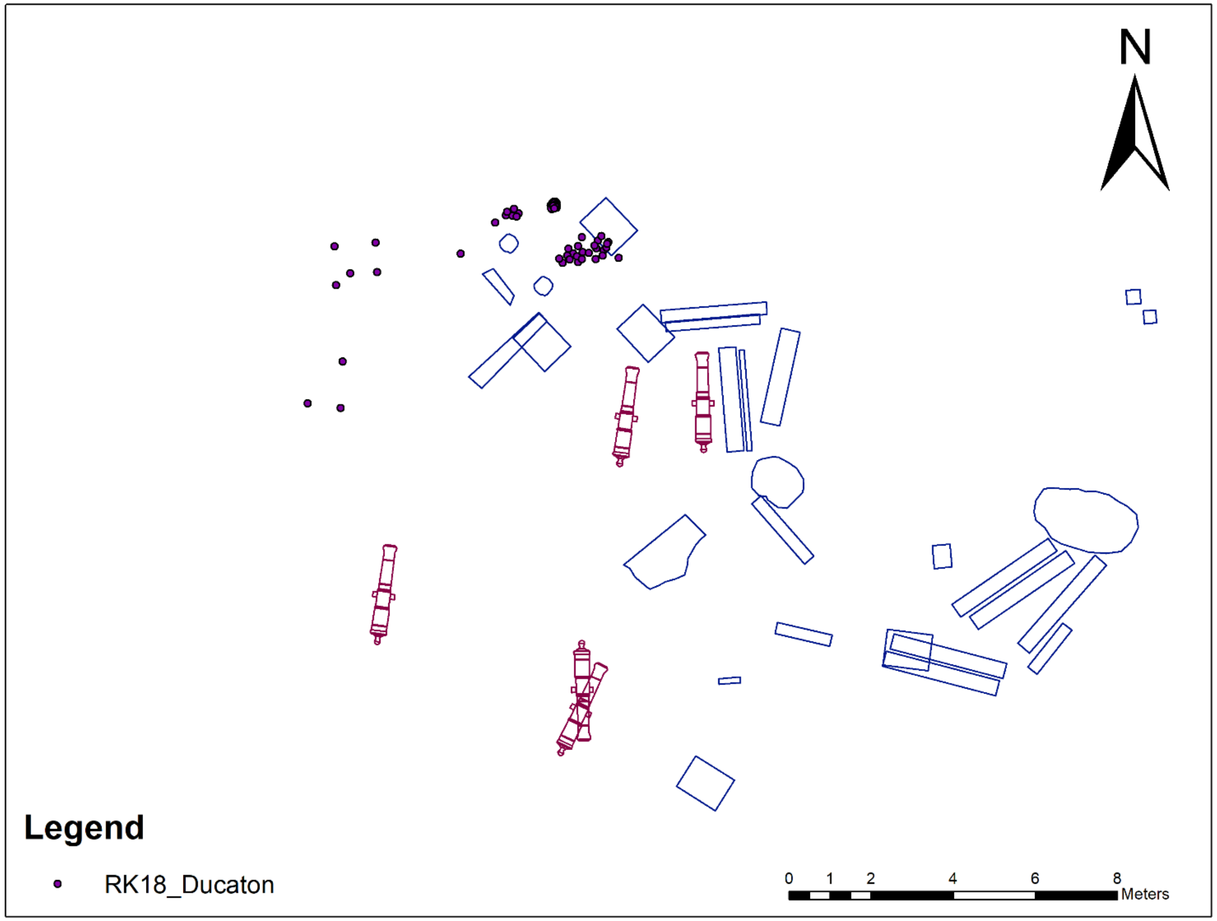


Figure 98. The figure shows the Ducaton distribution on the *Rooswijk*. The maps of artefact distribution where made with Site Recorder 4® and converted into Arc Map 10.5®. The author of this thesis created an image in ArcMap 10.5®.

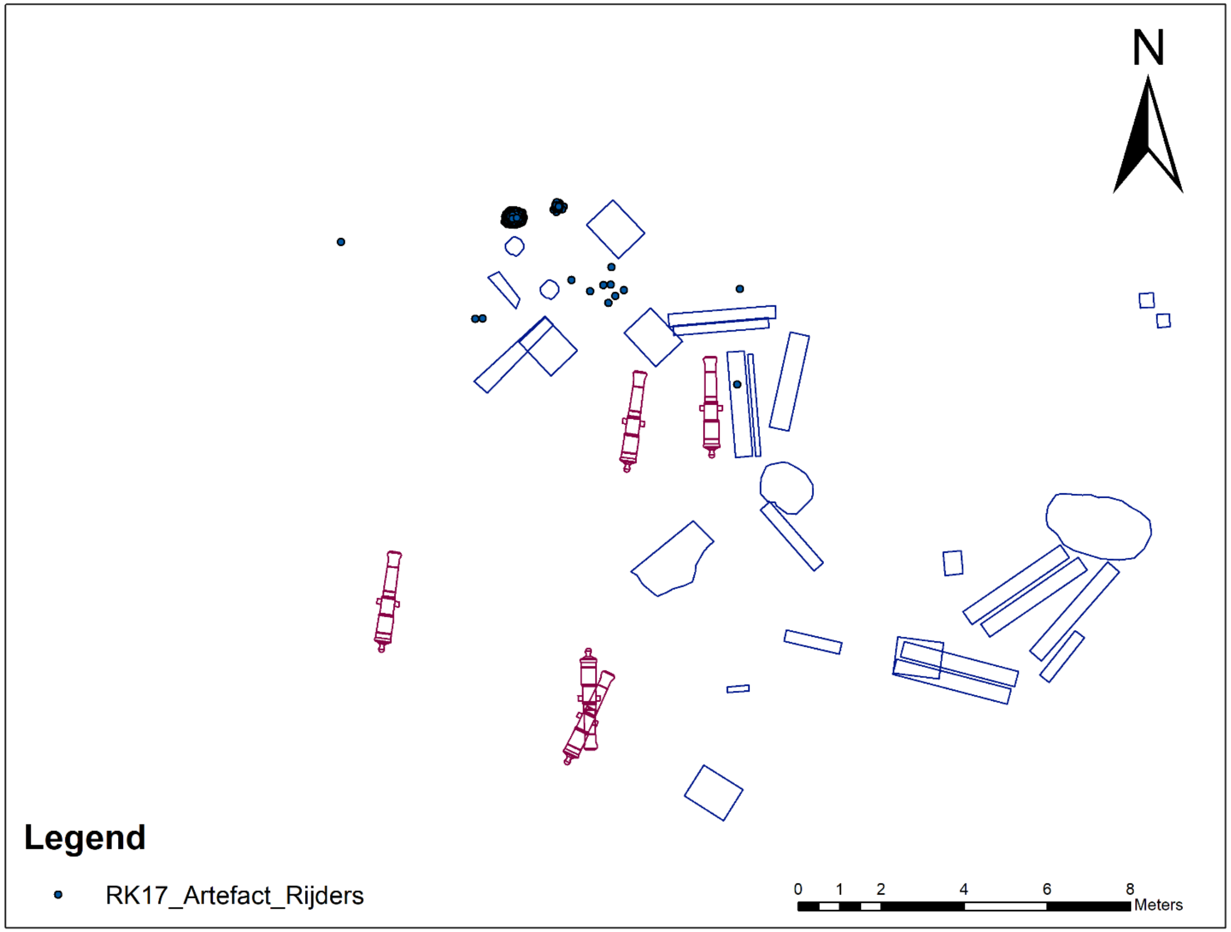


Figure 99. The figure shows the Rijders distribution on the *Rooswijk*. The maps of artefact distribution where made with Site Recorder 4® and converted into Arc Map 10.5®. The author of this thesis created an image in ArcMap 10.5®.

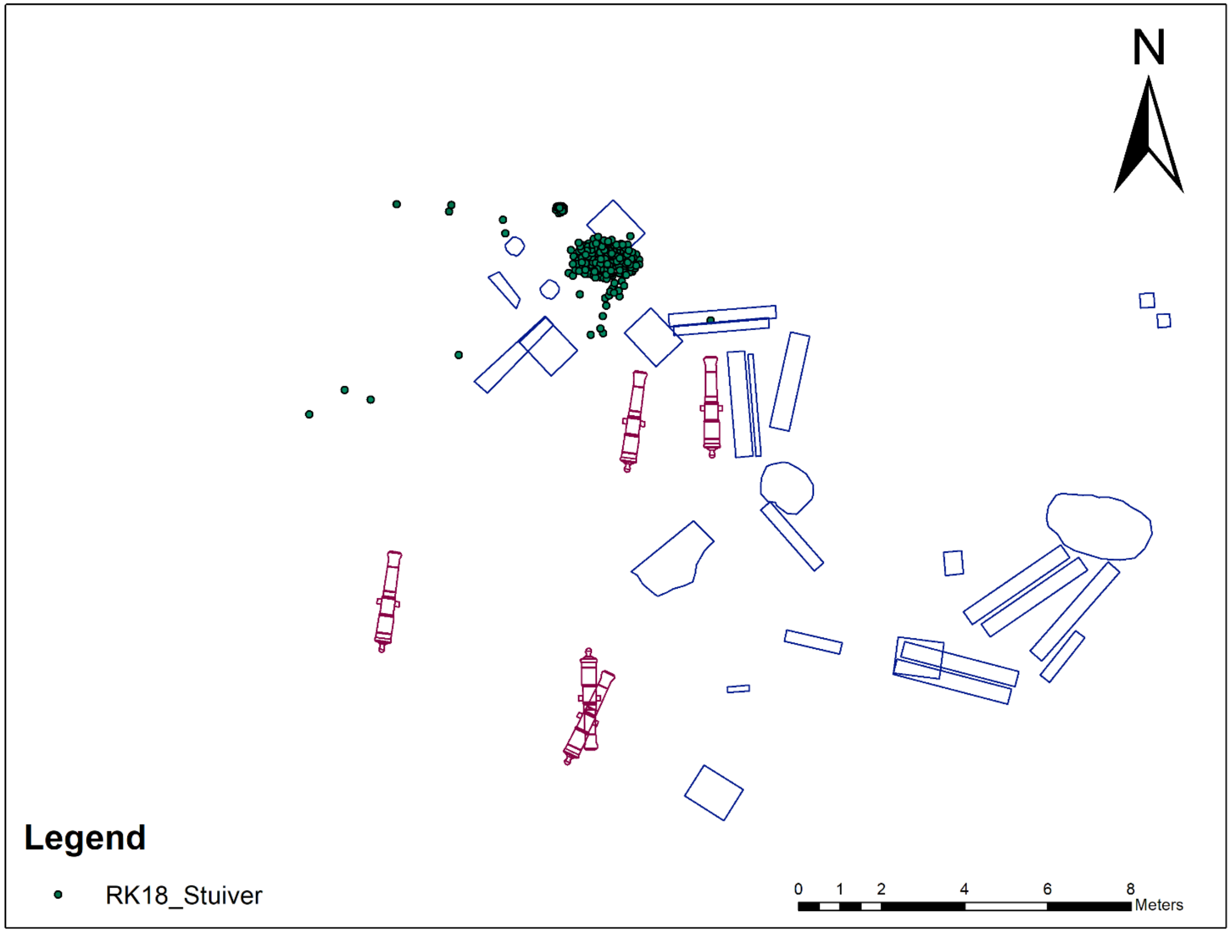


Figure 100. The figure shows Stuivers distribution on the *Rooswijk*. The maps of artefact distribution where made with Site Recorder 4® and converted into Arc Map 10.5®. The author of this thesis created an image in ArcMap 10.5®.

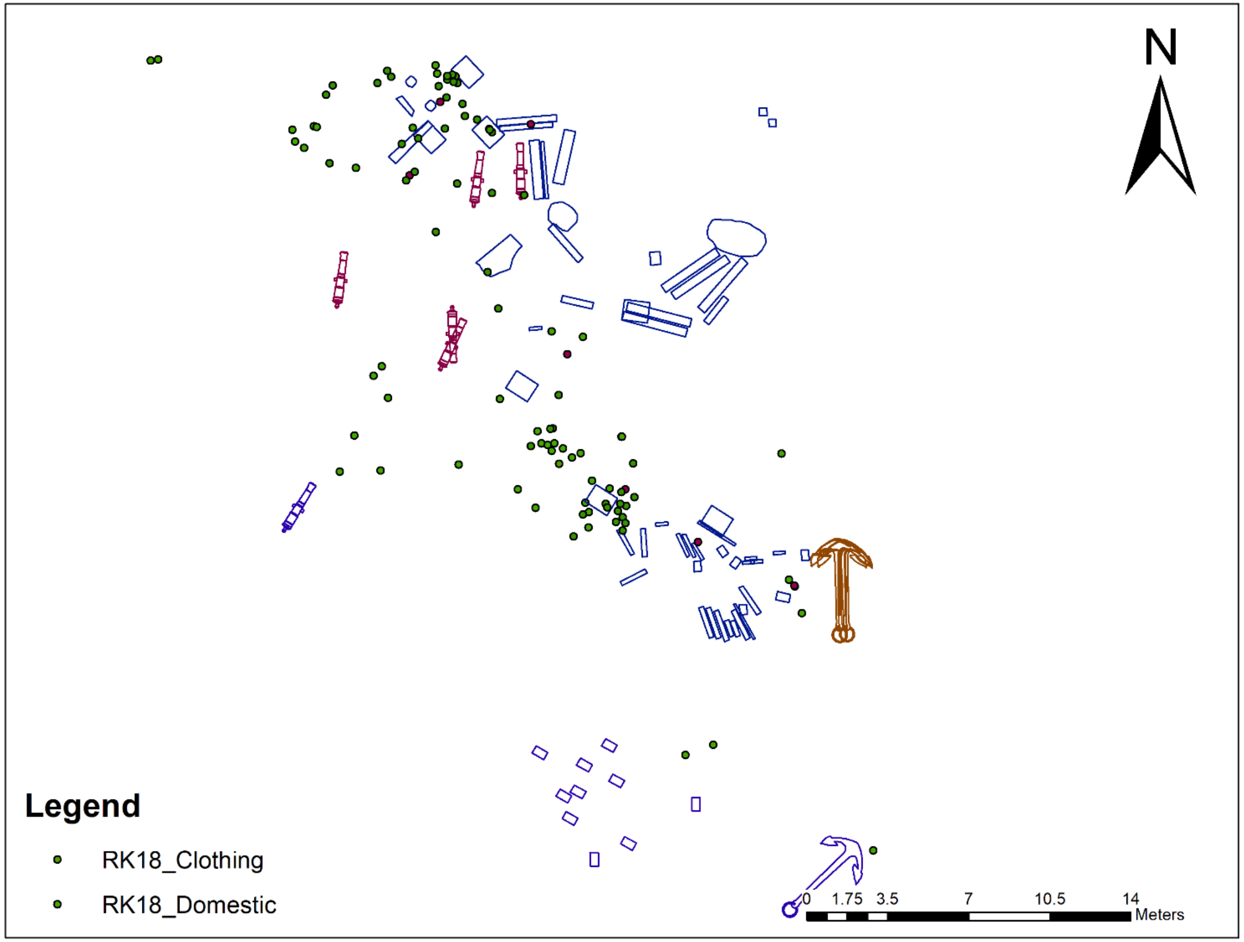


Figure 101. The figure shows the Clothing and Domestic artefacts distribution on the *Rooswijk*. The maps of artefact distribution where made with Site Recorder 4® and converted into Arc Map 10.5®. The author of this thesis created an image in ArcMap 10.5®.

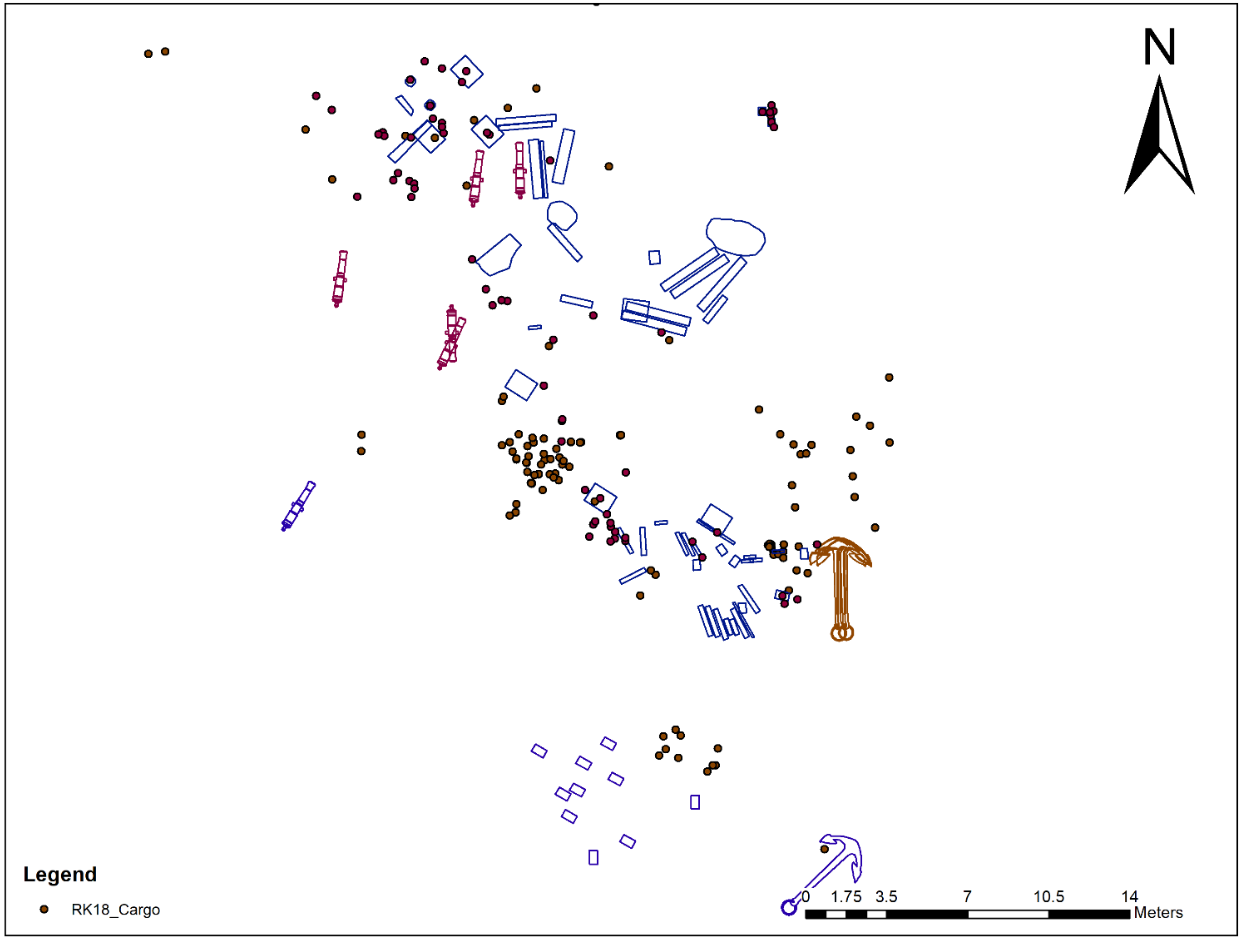


Figure 102. The figure shows the Cargo artefacts distribution on the *Rooswijk*. The maps of artefact distribution where made with Site Recorder 4® and converted into Arc Map 10.5®. The author of this thesis created an image in ArcMap 10.5®.

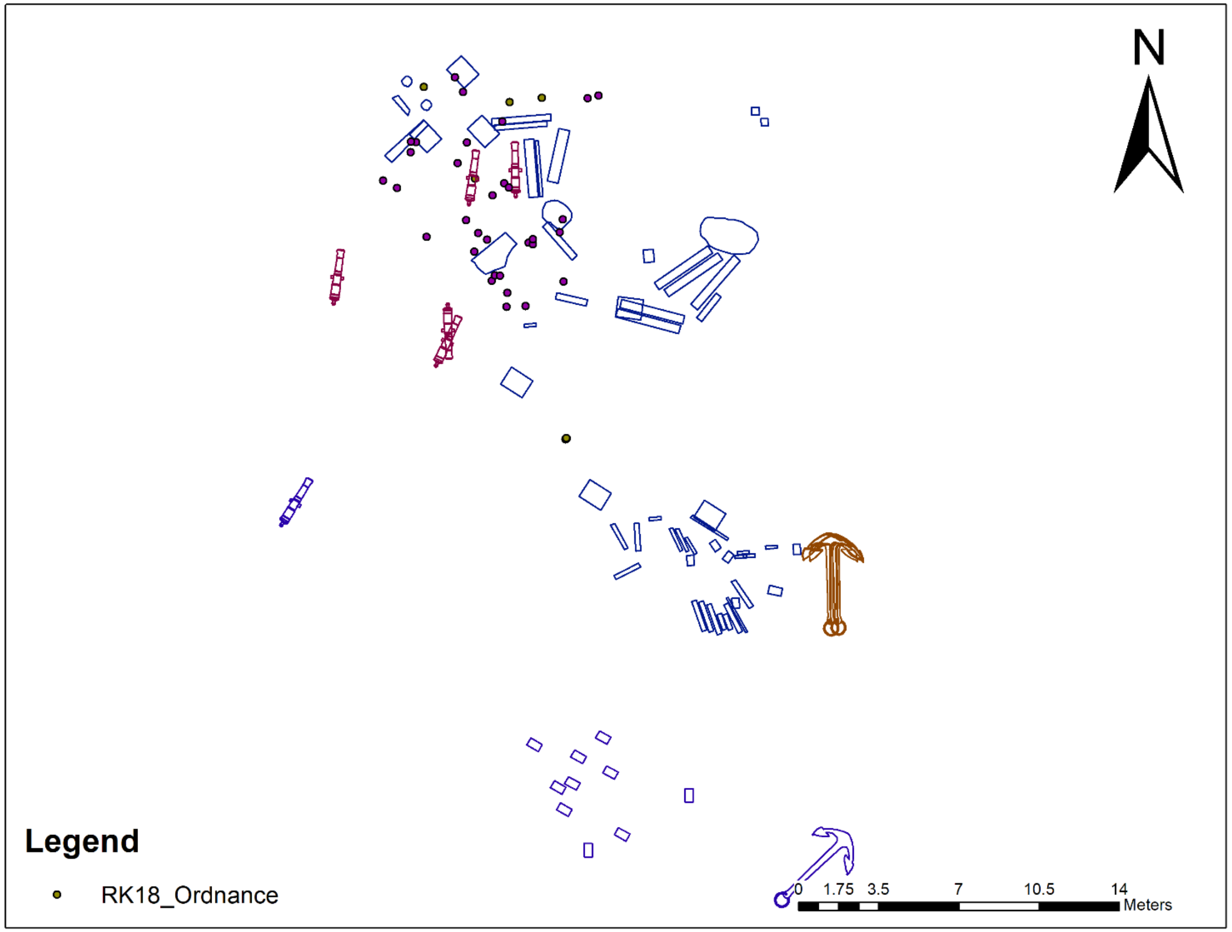


Figure 103. The figure shows the Ordnance artefacts distribution on the *Rooswijk*. The maps of artefact distribution where made with Site Recorder 4® and converted into Arc Map 10.5®. The author of this thesis created an image in ArcMap 10.5®.

2.B.6. Fieldwork

Figure 104. The image shows a diver recovering a Dutch Ducaton dated to 1739. Michael Pitts took the picture. The image is courtesy of Michael Pitts, kindly provided the *Rooswijk* Project 1740. The author of this thesis processed the picture.

Figure 105. The image shows a diver recovering a bronze breech block, with A VOC inscription (Chamber of Amsterdam). The image is courtesy of Michael Pitts, kindly provided the *Rooswijk* Project 1740. The author of this thesis processed the picture.

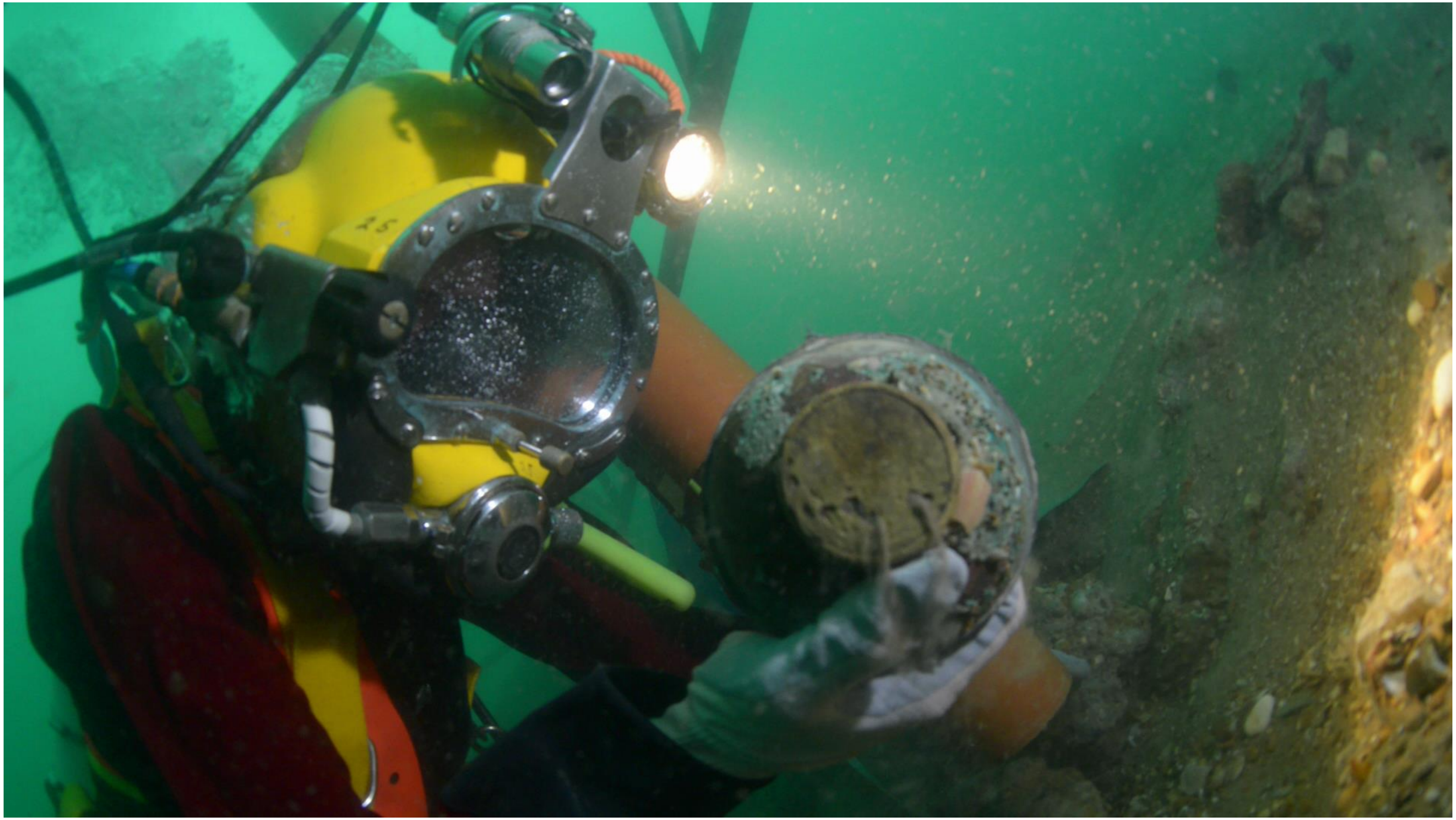


Figure 106. The image shows a diver recovering an oil lamp. The image is courtesy of Michael Pitts, kindly provided the *Rooswijk* Project 1740. The author of this thesis processed the picture.

Figure 107. The image shows a diver positioning the oil lamp with a USBL system. The image is courtesy of Michael Pitts, kindly provided the *Rooswijk* Project 1740. The author of this thesis processed the picture.

C. HMS *Invincible* 1744-1758 (Chapter VII)

- Historical
- Geophysics
- Photogrammetry
- Fieldwork

2.C.1 Historical. *Invincible* 1744-1758

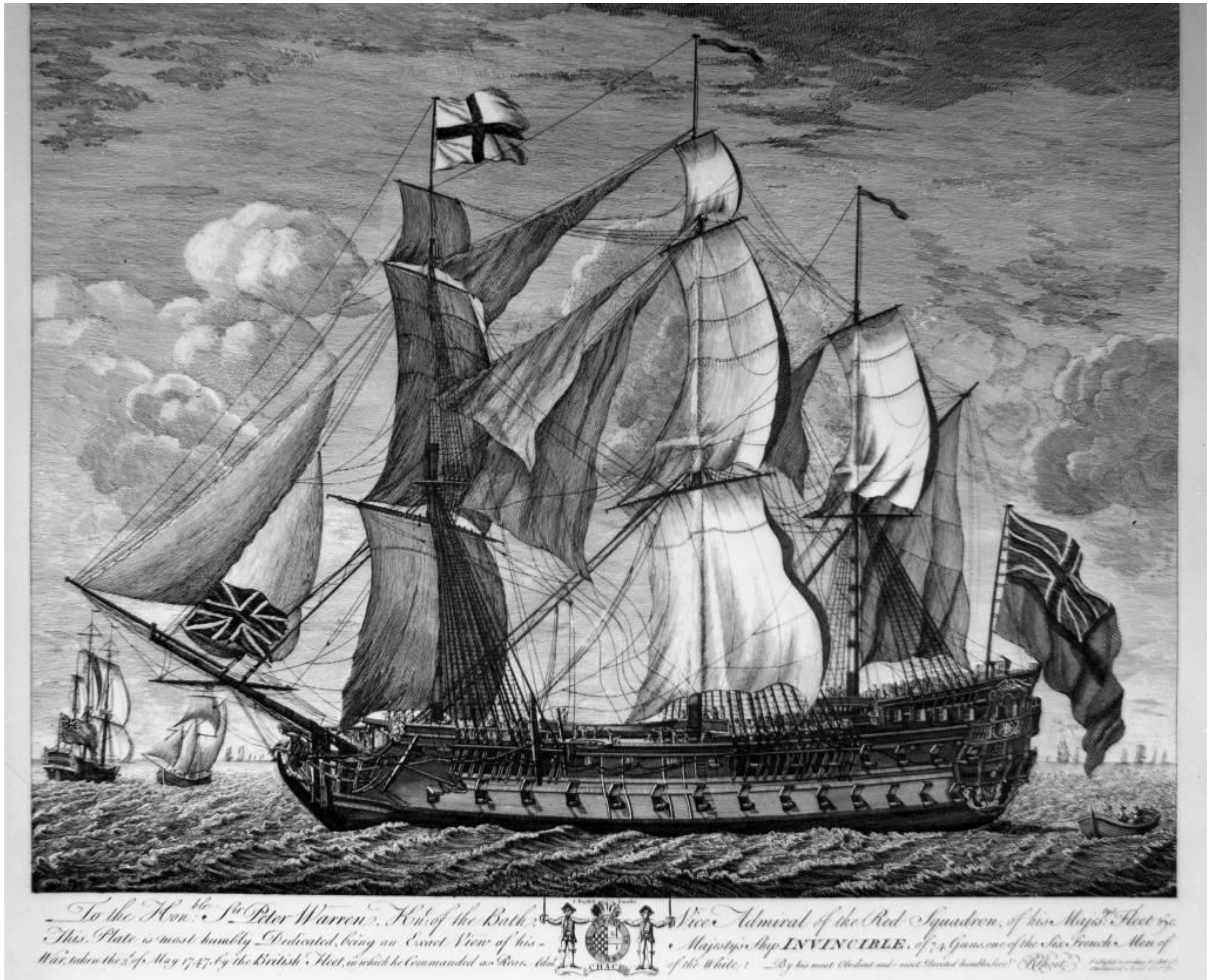


Figure 108 The illustration shows HMS *Invincible* with full rigging (Mynd, Boydell, and Short 1747).

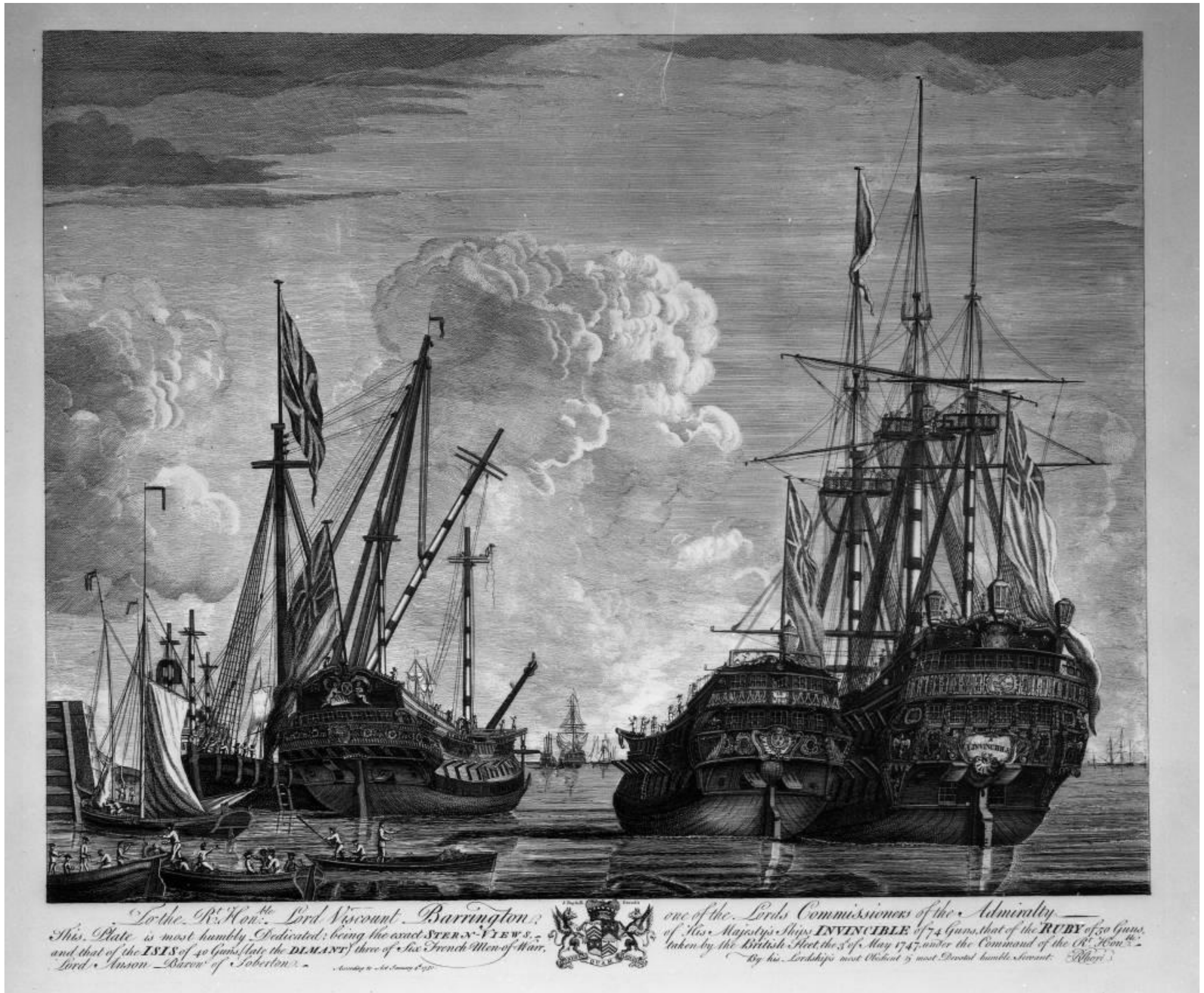


Figure 109. Engraving of *Ruby*, *Isis*, and *Invincible* (right) under repair at Portsmouth Dockyard following after her capture in 1747-1748.

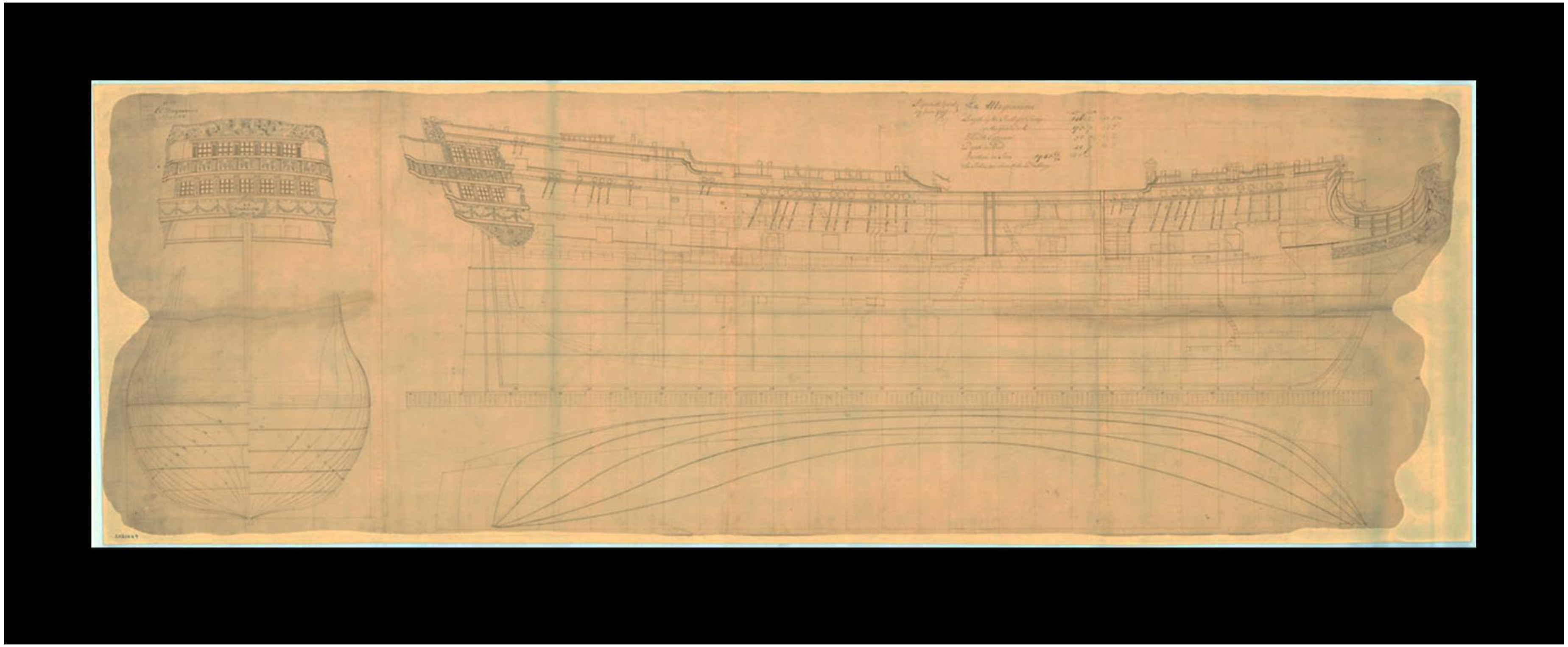


Figure 110. ***Le Magnanime*** **captured in 1758. Ship plan was drawn in Plymouth after capture and taken for repair, currently held at the NMM in Greenwich, London (Unkown 1758)**

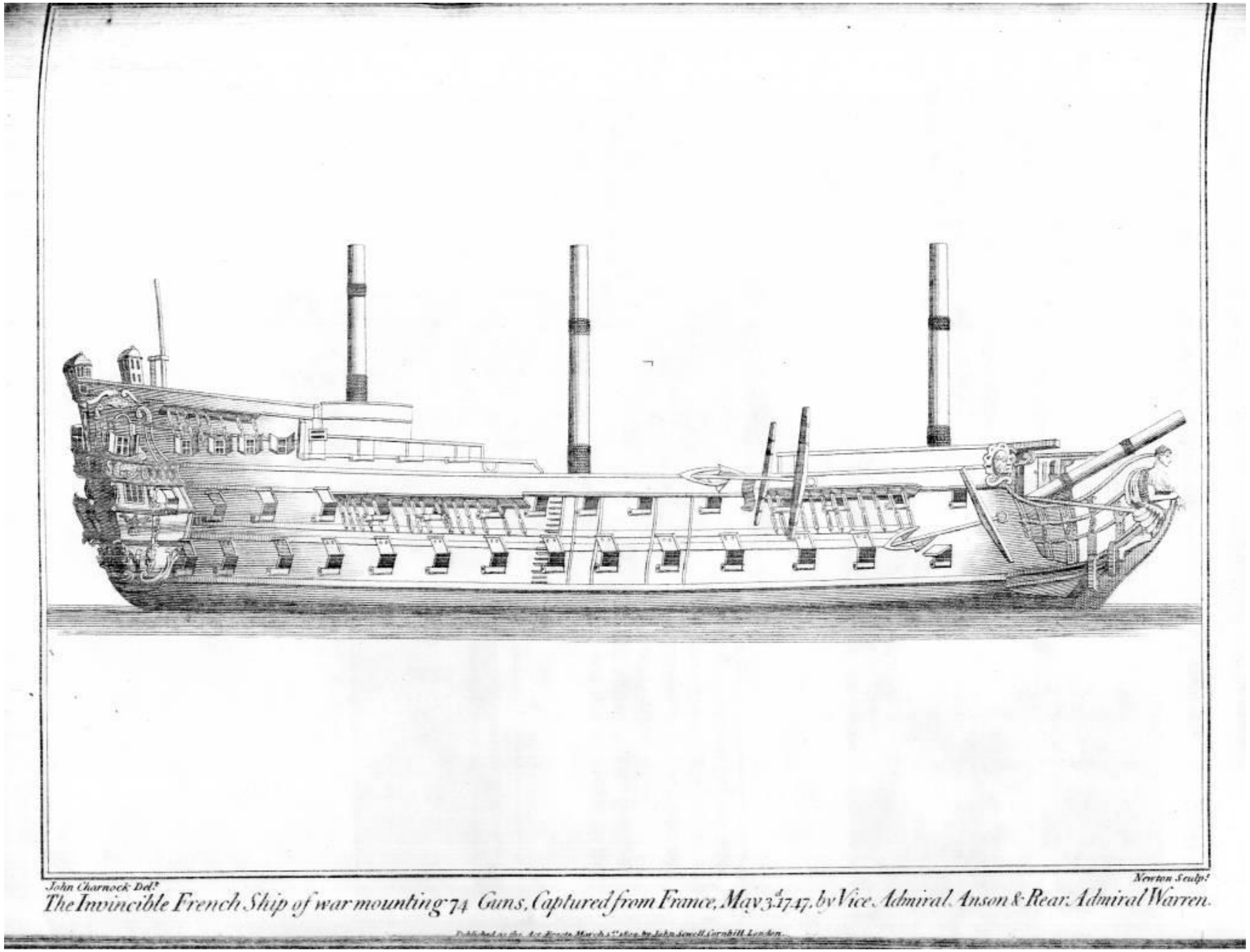


Figure 111. *Invincible* captured in 1744. NNM by Charnock (Newton Charnock n.d.)

Figure 112. The image shows a plan of the Royal Docks at Portsmouth, with a detailed description of the ships docked there. On the top a highlighted image with the *Invincible* (F) (Canot 1754). The original is held at the Royal Collection Trust.

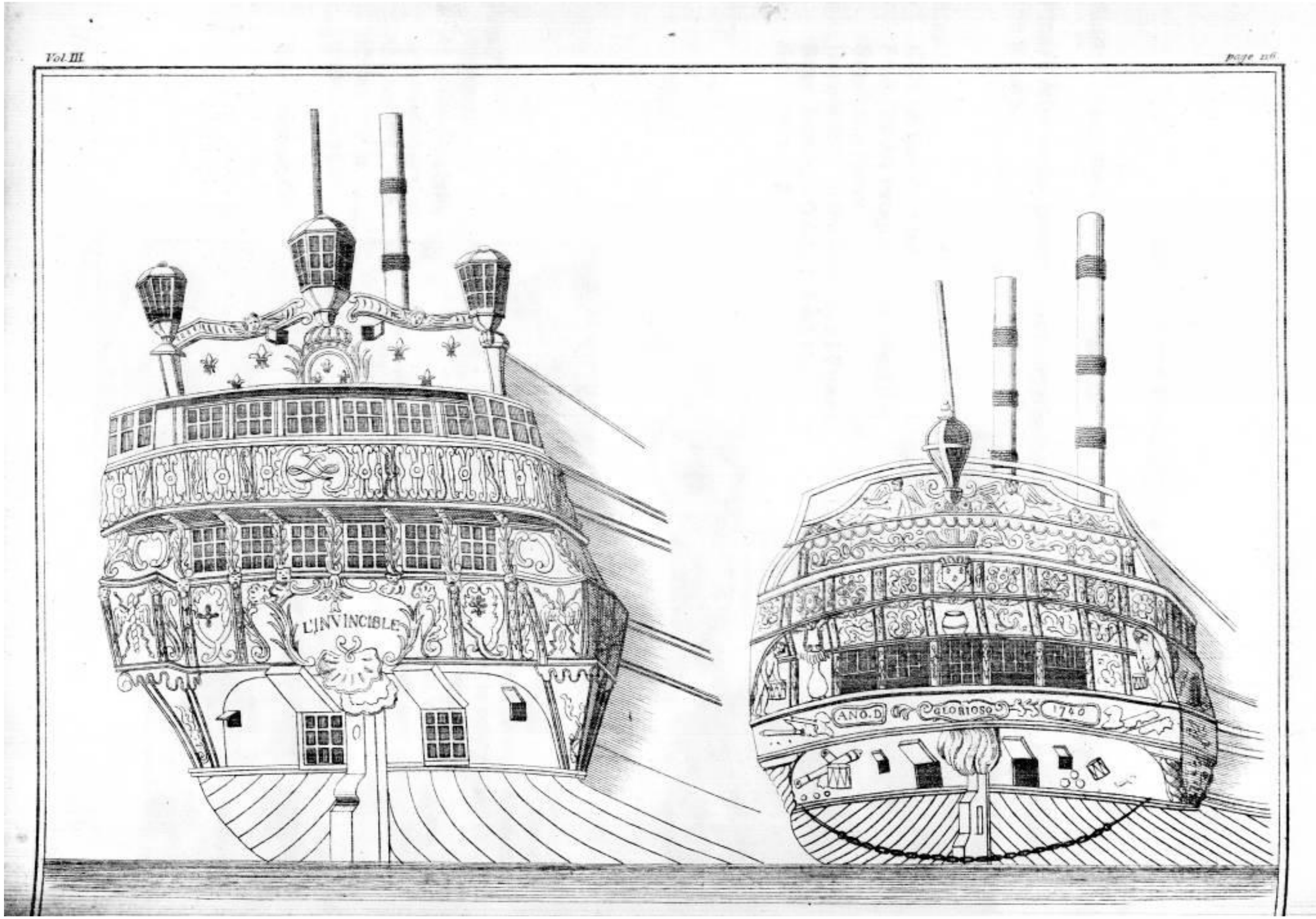


Figure 113. NMM. The illustrations show details and decorations on the stern of *Invincible* on the left and *Glorioso* on the right (Fincham 1851:84–85).

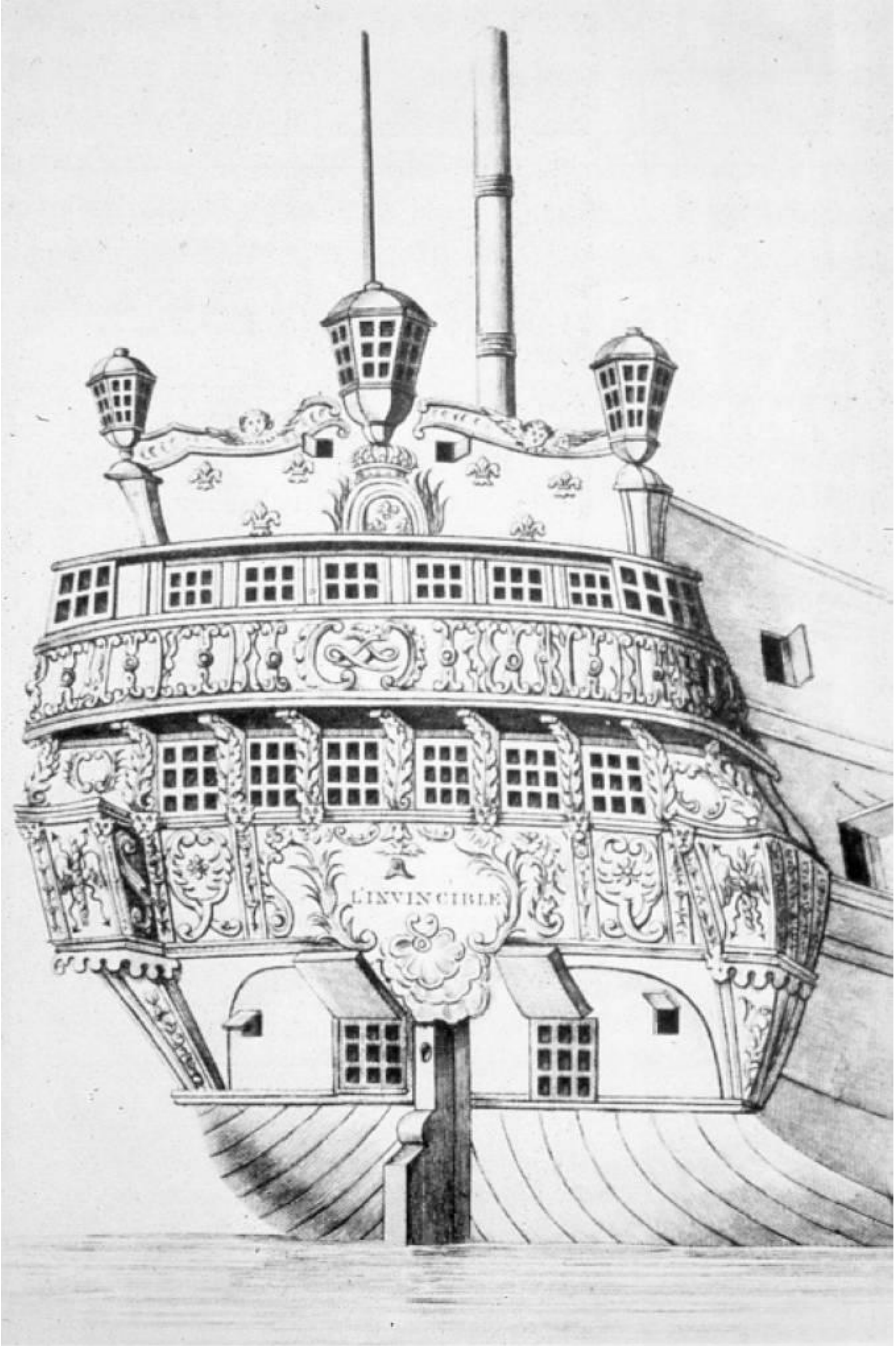


Figure 114. Invincible by John Hood NNM, Greenwich, London (Hood n.d.

Figure 115. The battle of Cape Finisterre 3rd May 1747. During this naval battle, *Invincible* was captured and taken into Portsmouth. (Scott n.d.). **The original is held at the Tate museum and NNM.**

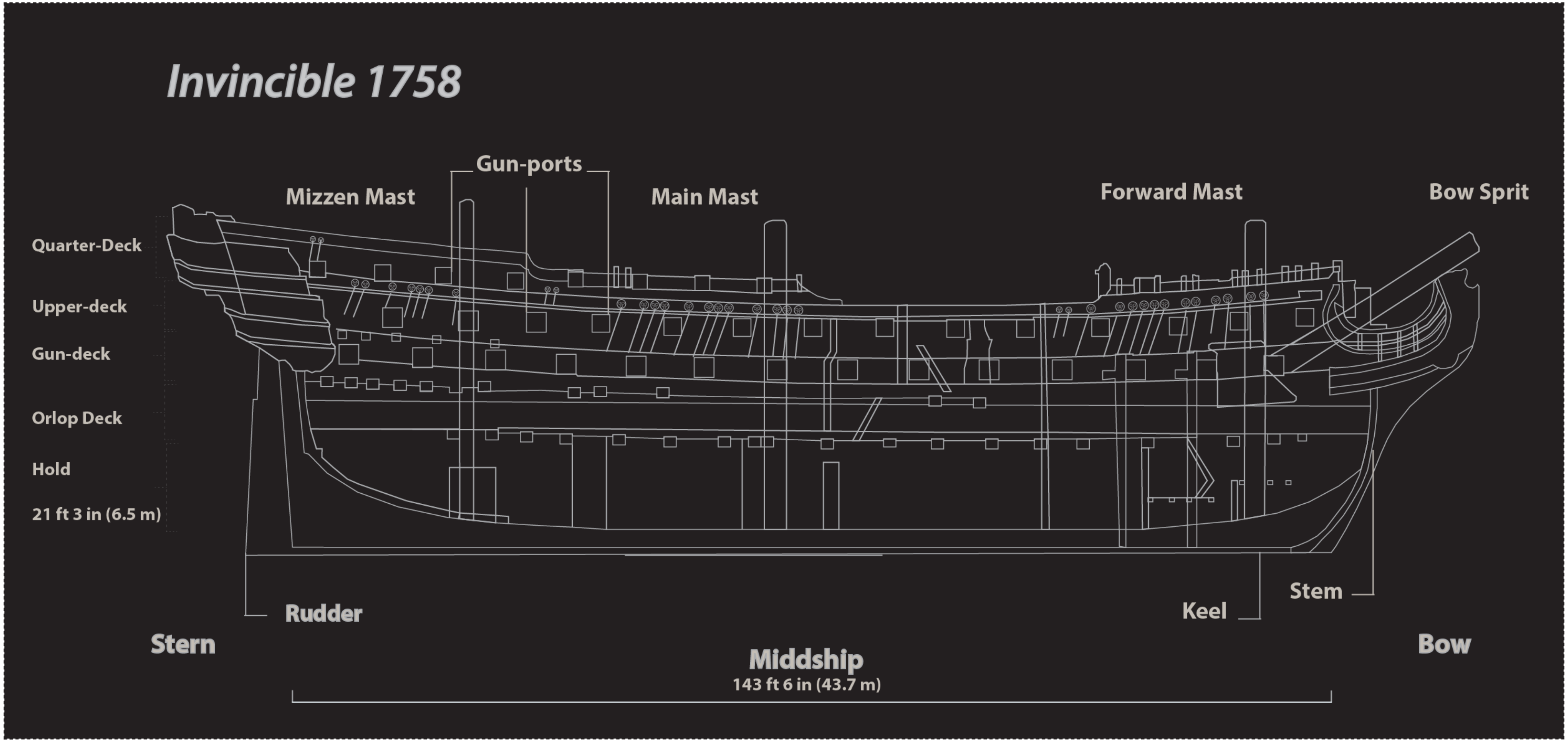


Figure 116. The figure was created by the author of this thesis, *Invincible* line plans based on *Le Magnanime*.

2.C.2 Geophysics. *Invincible* 1744-1758

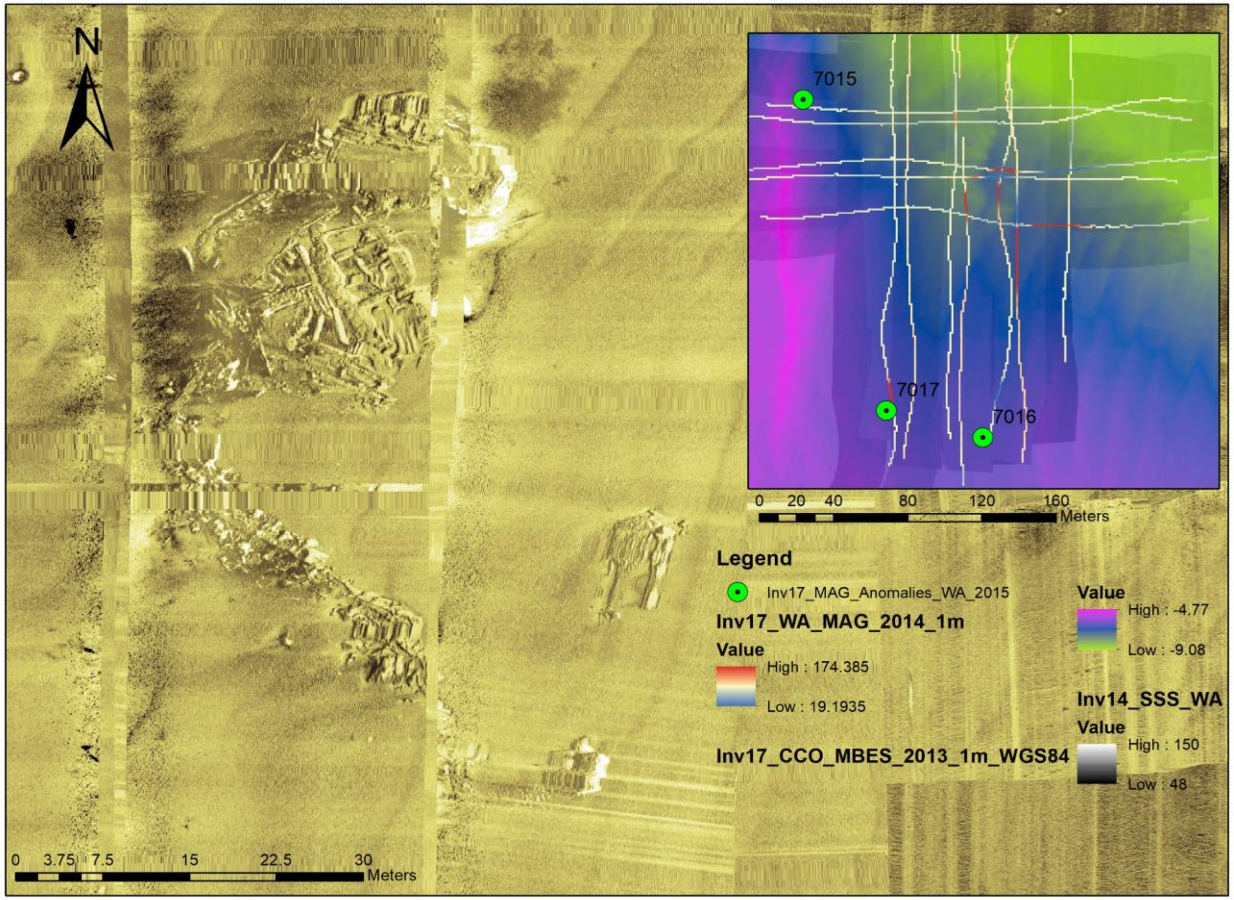


Figure 117. The figure shows Side Scan Sonar survey and Magnetometer (on top right) surveys carried out by WA in 2014. The author of this thesis created the map in ArcMap 10.5®.

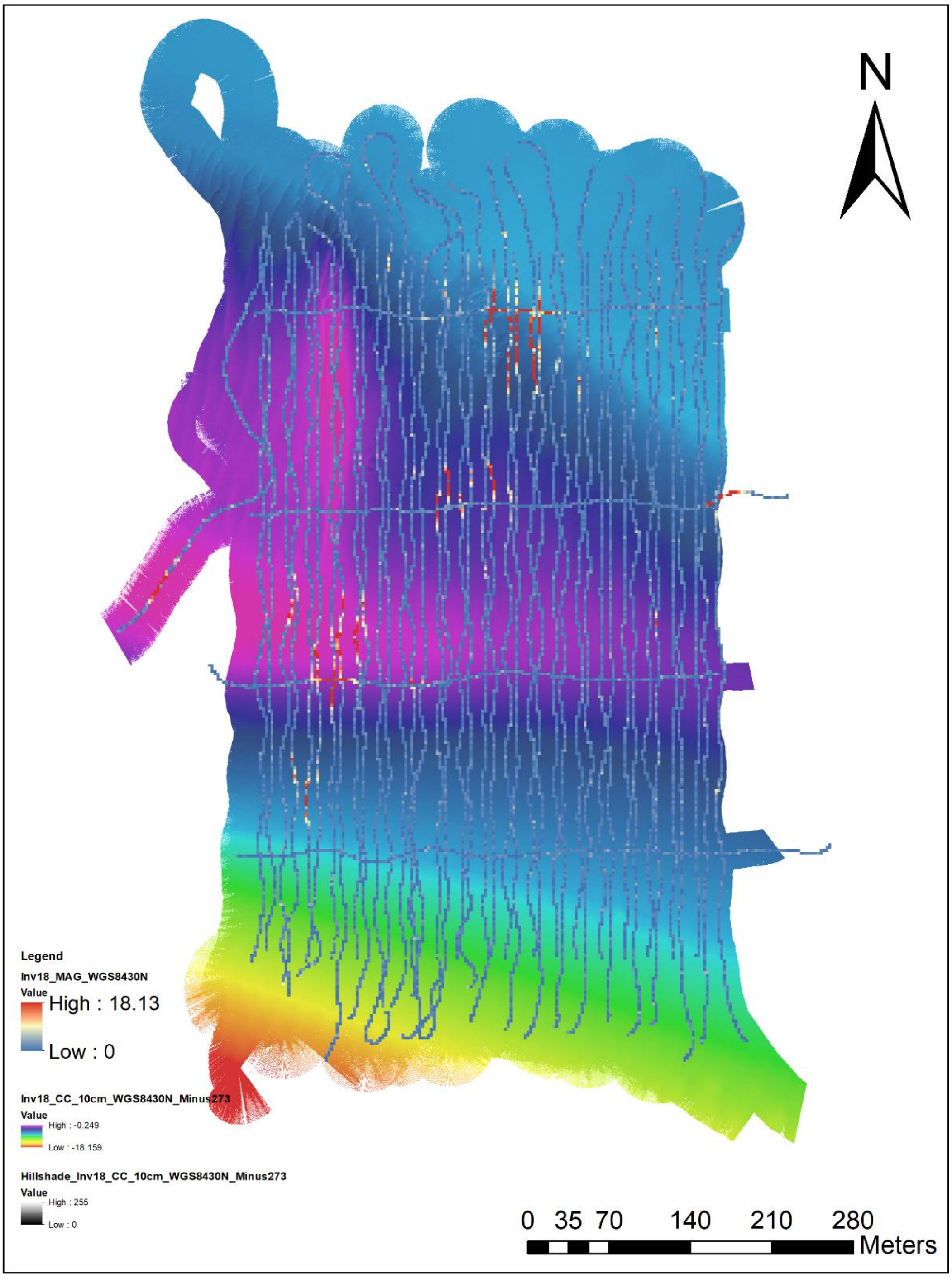


Figure 118. A magnetometer survey carried out in 2018 by BU on *Invincible*. The data is courtesy of BU. The figure was created by the author in ArcMap 10.5 ®.

2.C.3 Photogrammetry. *Invincible* 1744-1758

Trench 1 (covers Area 1)

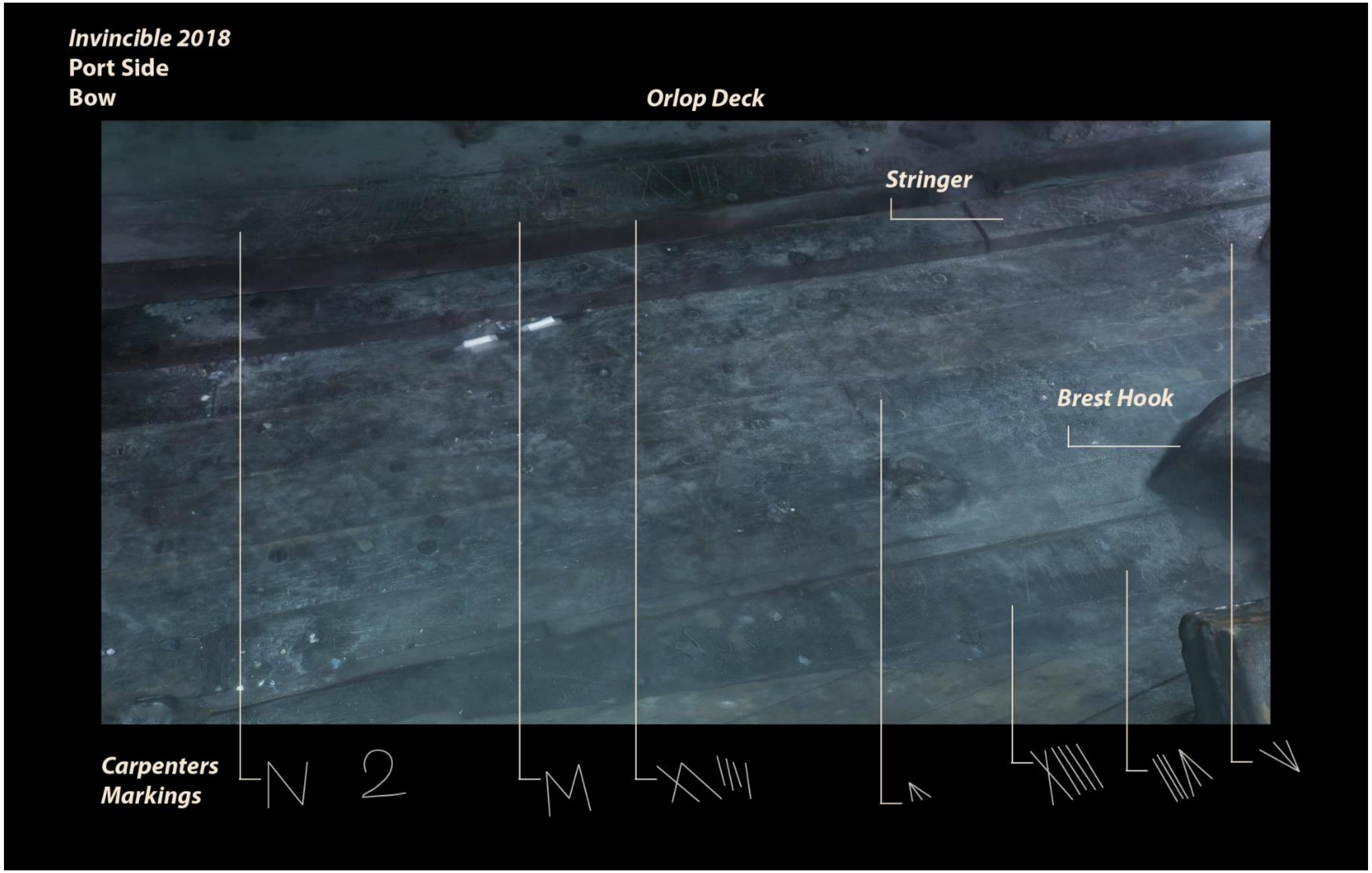


Figure 119. The figure shows some of the ship construction details found on *Invincible,* in Area 1 on the bow section. The image is based on a high-resolution photogrammetry survey done in 2017 and post-processing on 3Dsmax®. The author of this thesis made the figure.

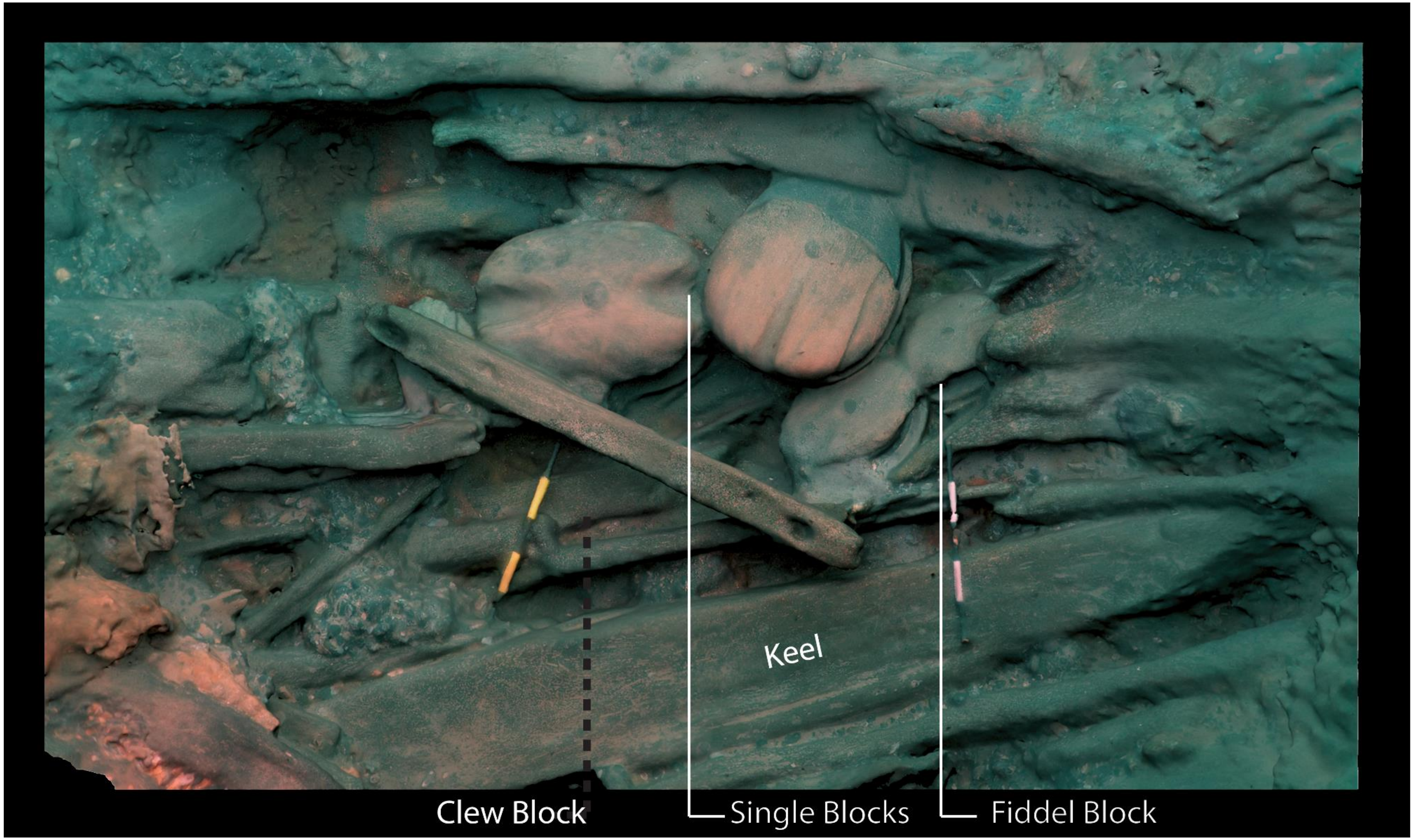


Figure 120. The figure shows pulley blocks found on *Invincible,* in Area 1 on the bow section. The image is based on a high-resolution photogrammetry survey done in 2017 and post-processing on 3Dsmax®. The author of this thesis made the figure.

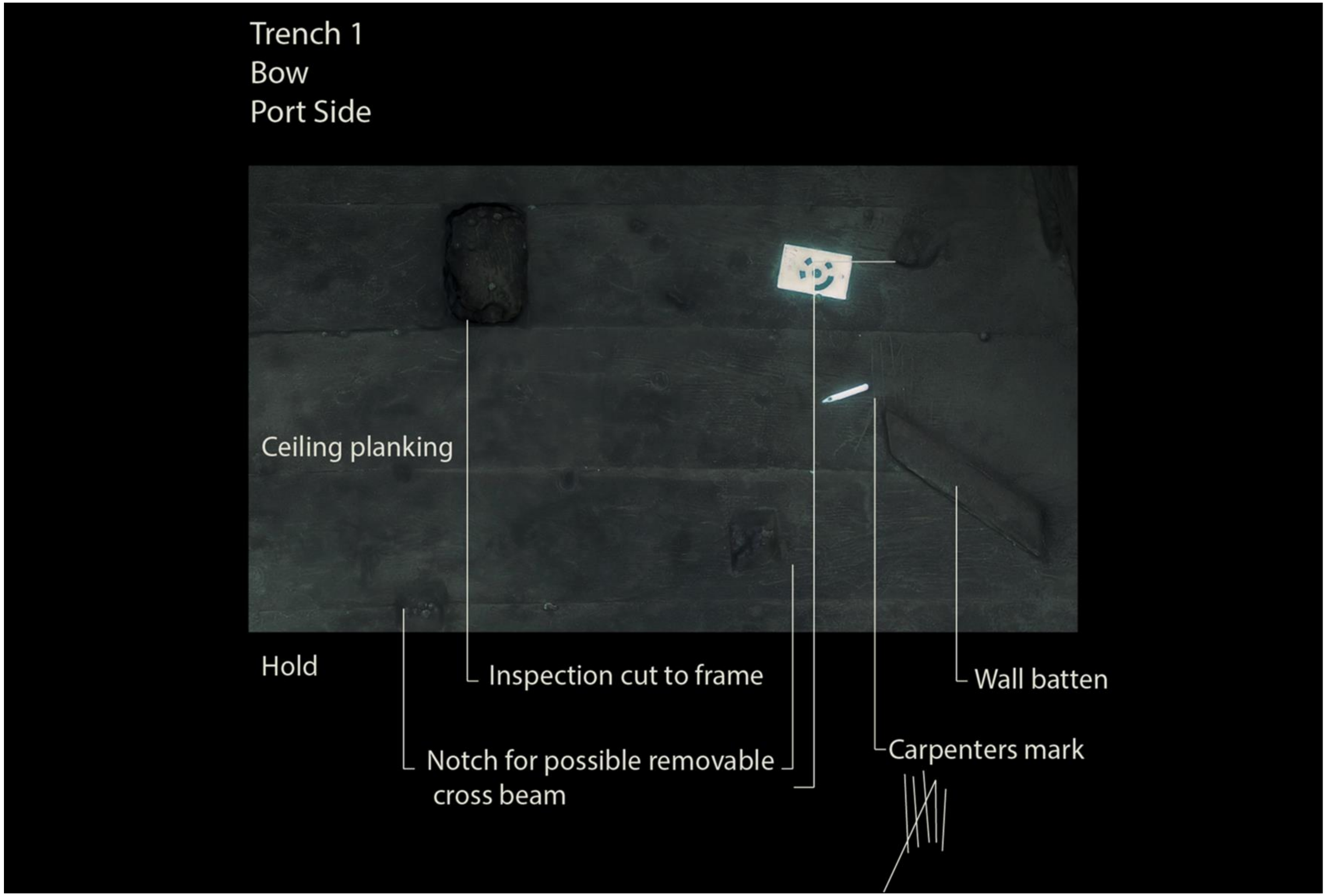


Figure 121. The image was rendered on 3dsMax® based on a photogrammetry model made on Agisoft Metashape Pro v1.5 ®. The image shows a close-up detailed of carpenter's marks in Trench 1 (Area 1), surveyed in 2018. The author of this thesis made the figure.

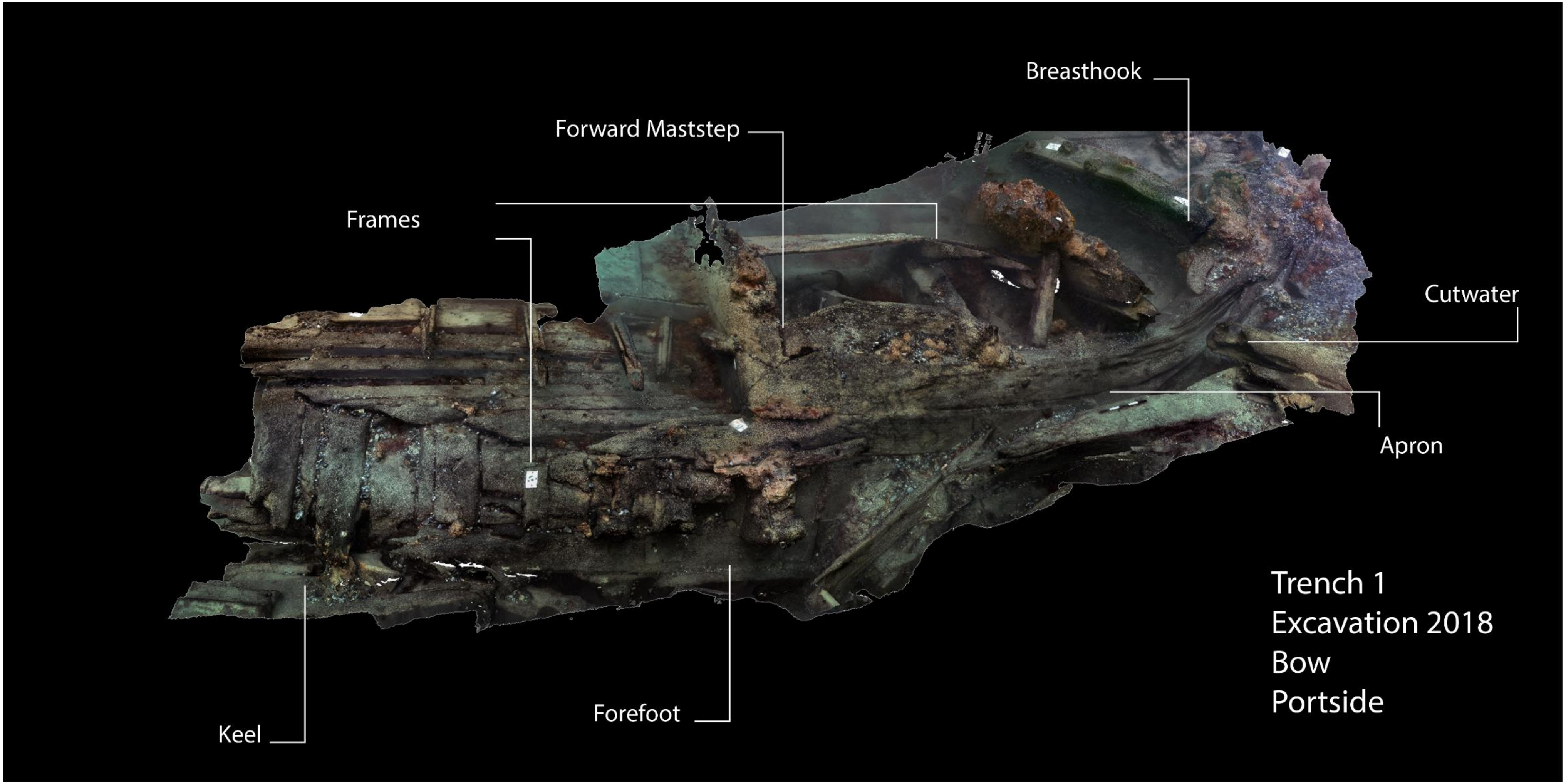


Figure 122. The image was rendered on 3dsMax® based on a photogrammetry model made on Agisoft Metashape Pro v1.5 ®. The image shows a close-up detailed model on the Keel, Keelson, and Stem in Trench 1 (Area 1), surveyed in 2018. The author of this thesis made the figure.

Trench 2

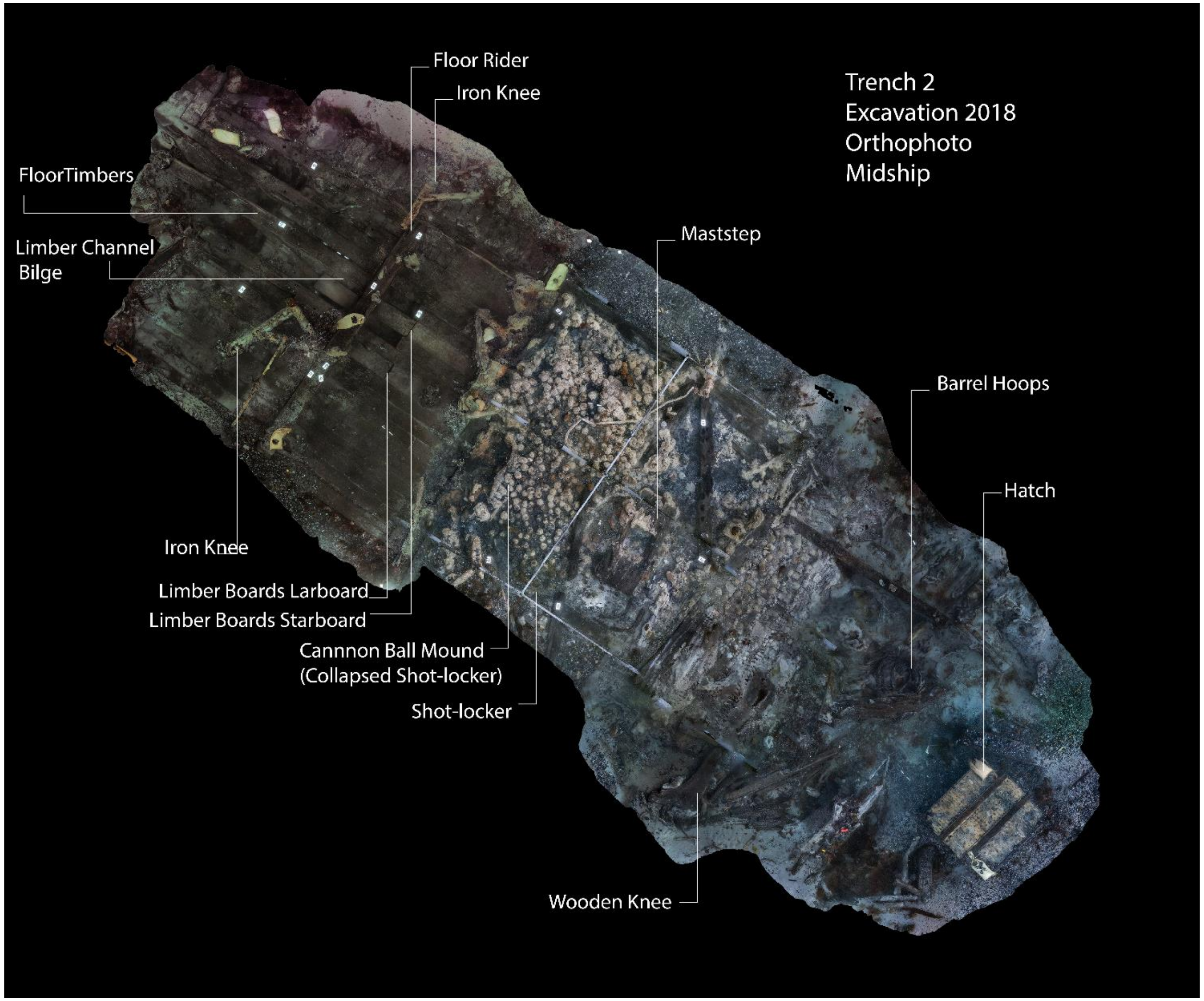


Figure 123. This is an orthophoto of Trench 2 excavated in 2018, showing the best-preserved part of the bottom of the ship. The author of this thesis made the figure.

2.C.4. Field Work

Figure 124. The image shows part of the Gun Stores in Area 1 close to the bow, in the stores exposed in 2017. The image is courtesy of Michael Pitts, kindly provided by BU and the Invincible 1744 Project.

Figure 125. The image shows part of the Orlop deck in Area 1 close to the bow, exposed in 2017. Michael Pitts took the picture. The image is courtesy of Michael Pitts, kindly provided by BU and the Invincible 1744 Project.

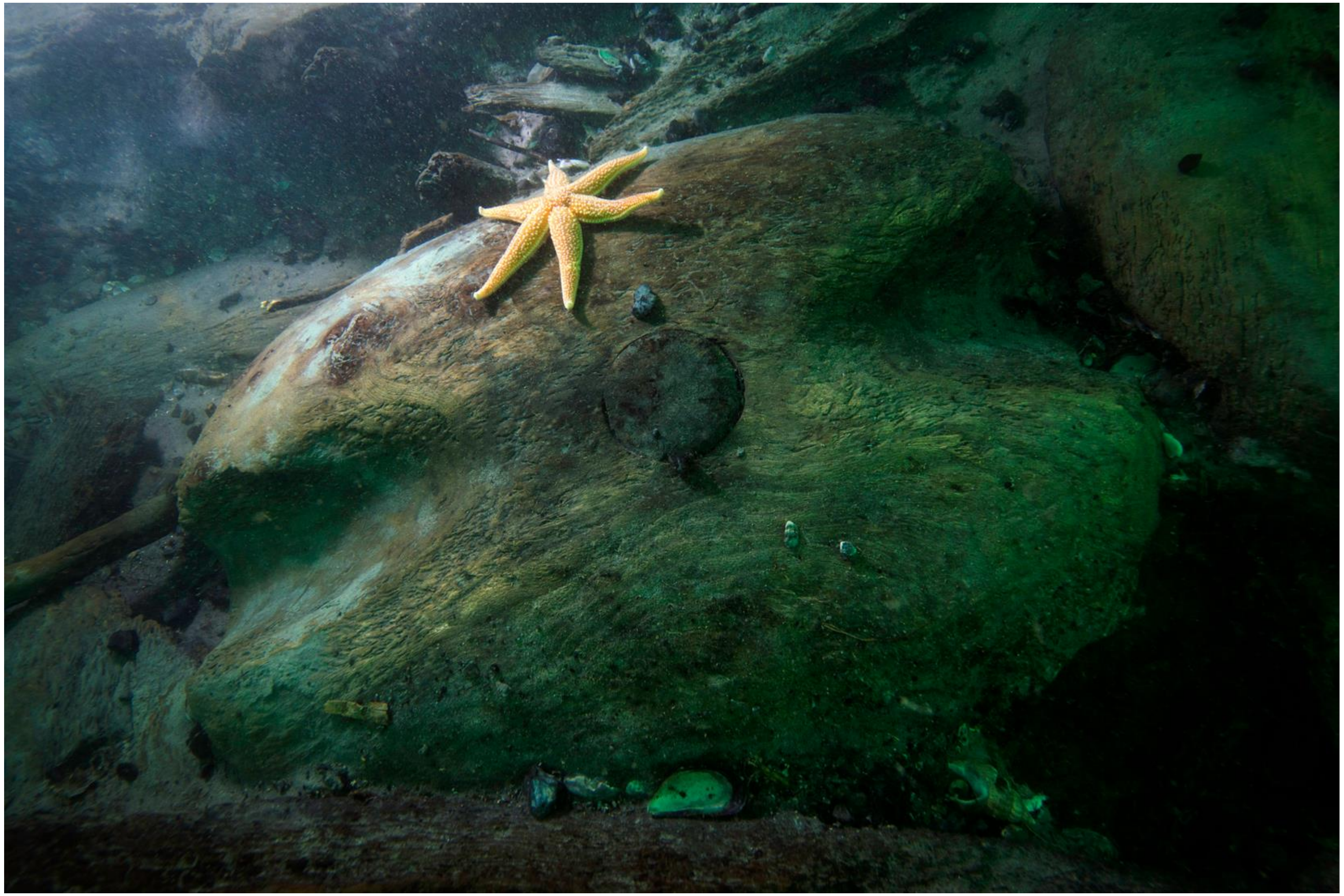


Figure 126. The image shows part of the pulley block found in the hold, close to the keel and stem, in the stores exposed in 2017. The image is courtesy of Michael Pitts, kindly provided by BU and the Invincible 1744 Project.

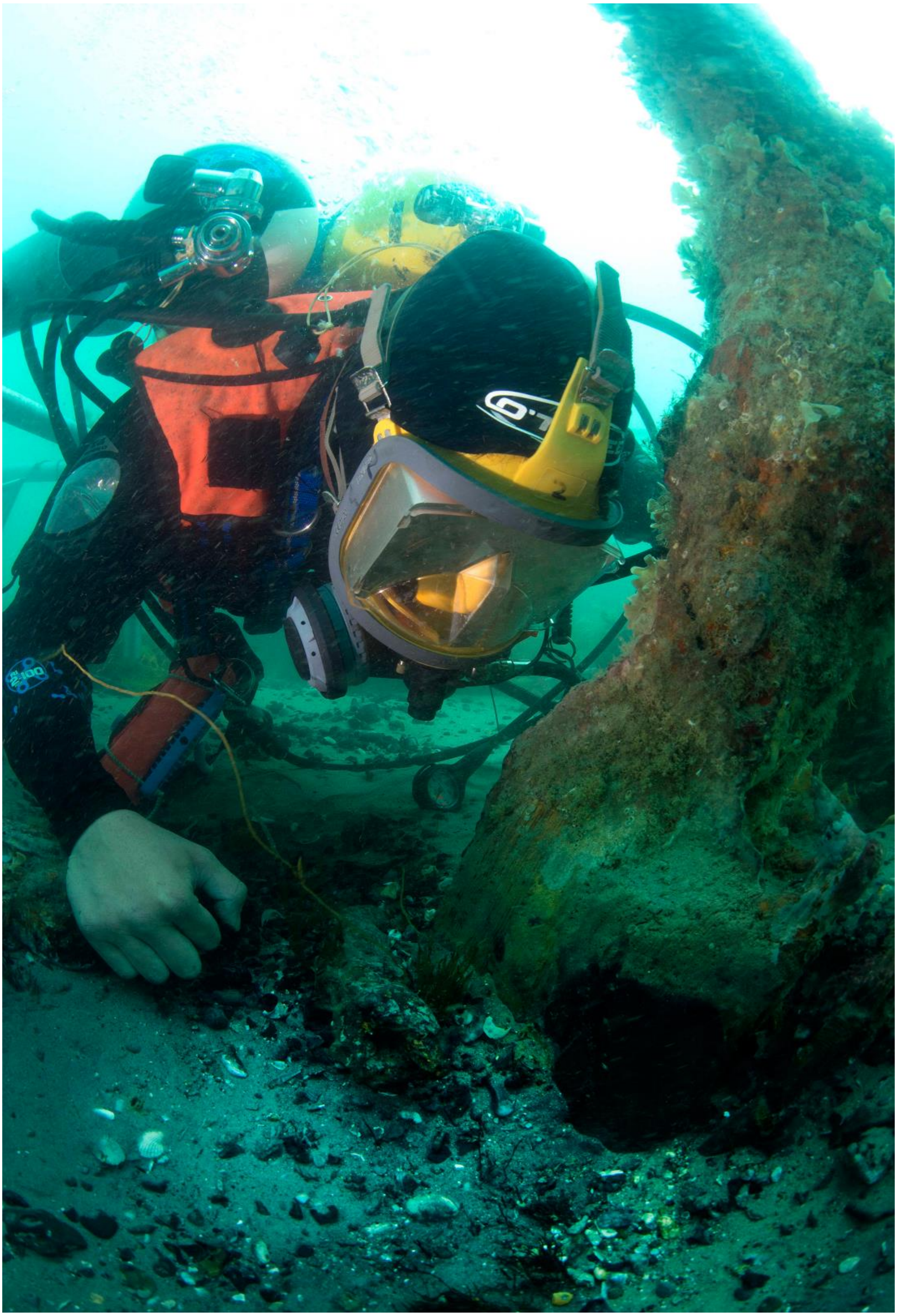


Figure 127. The image shows an iron knee supporting the gun deck, exposed in 2017. The image is courtesy of Michael Pitts, kindly provided by BU and the Invincible 1744 Project.

Appendix III. Notes on Discussions and Conclusion (Chapter VIII)

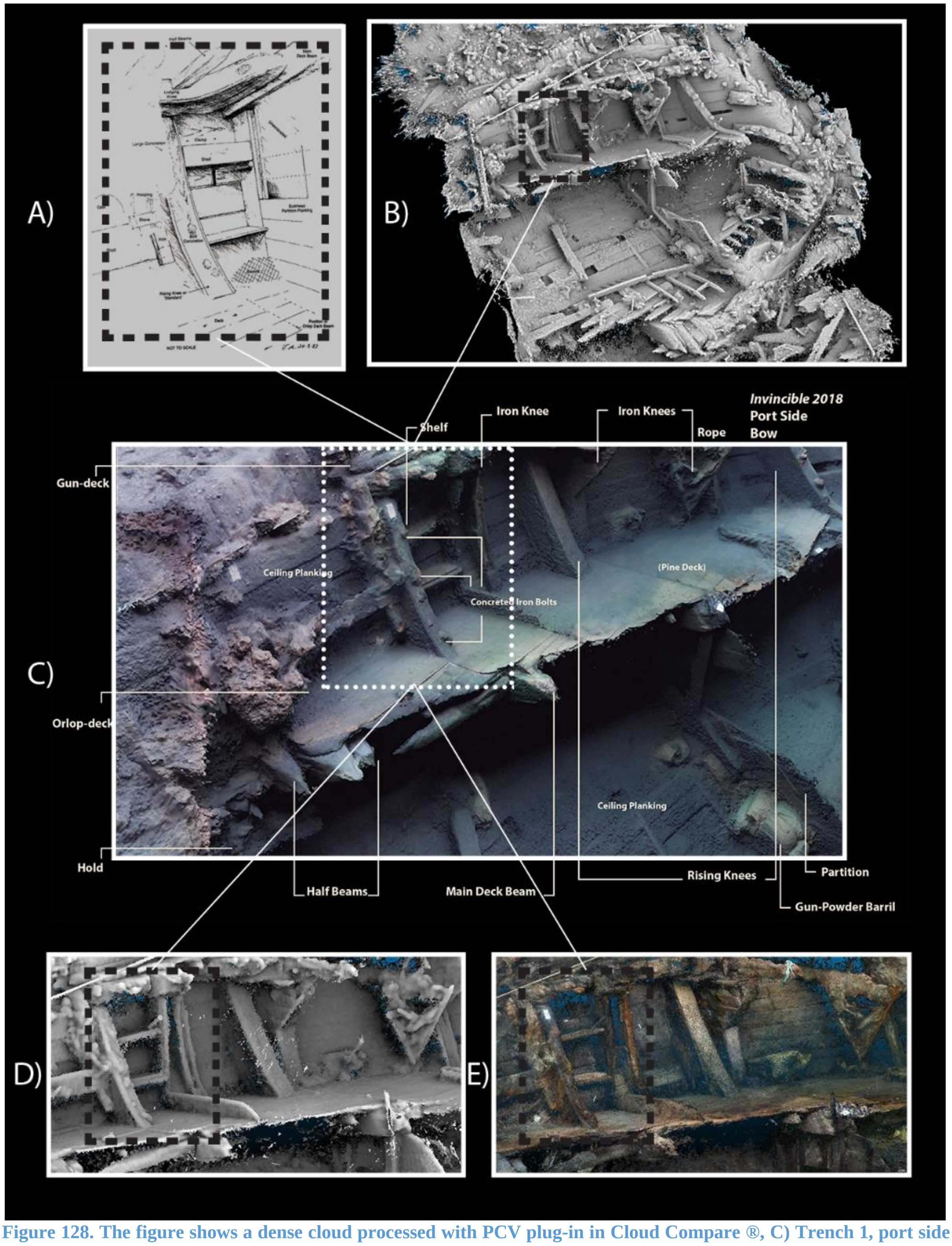


Figure 128. The figure shows a dense cloud processed with PCV plug-in in Cloud Compare ®, C) Trench 1, port side close to the bow rendered in 3dSMax®, D) Close-up of shelving A dense loud with PCV plug-in in Cloud Compare ®, and E) RGB colours of dense cloud in Cloud Compare

Figure 129. The figure shows a dense cloud of Trench 1, processed with PCV plug-in in Cloud Compare®. Set to the correct orientation, tilted on even keel.

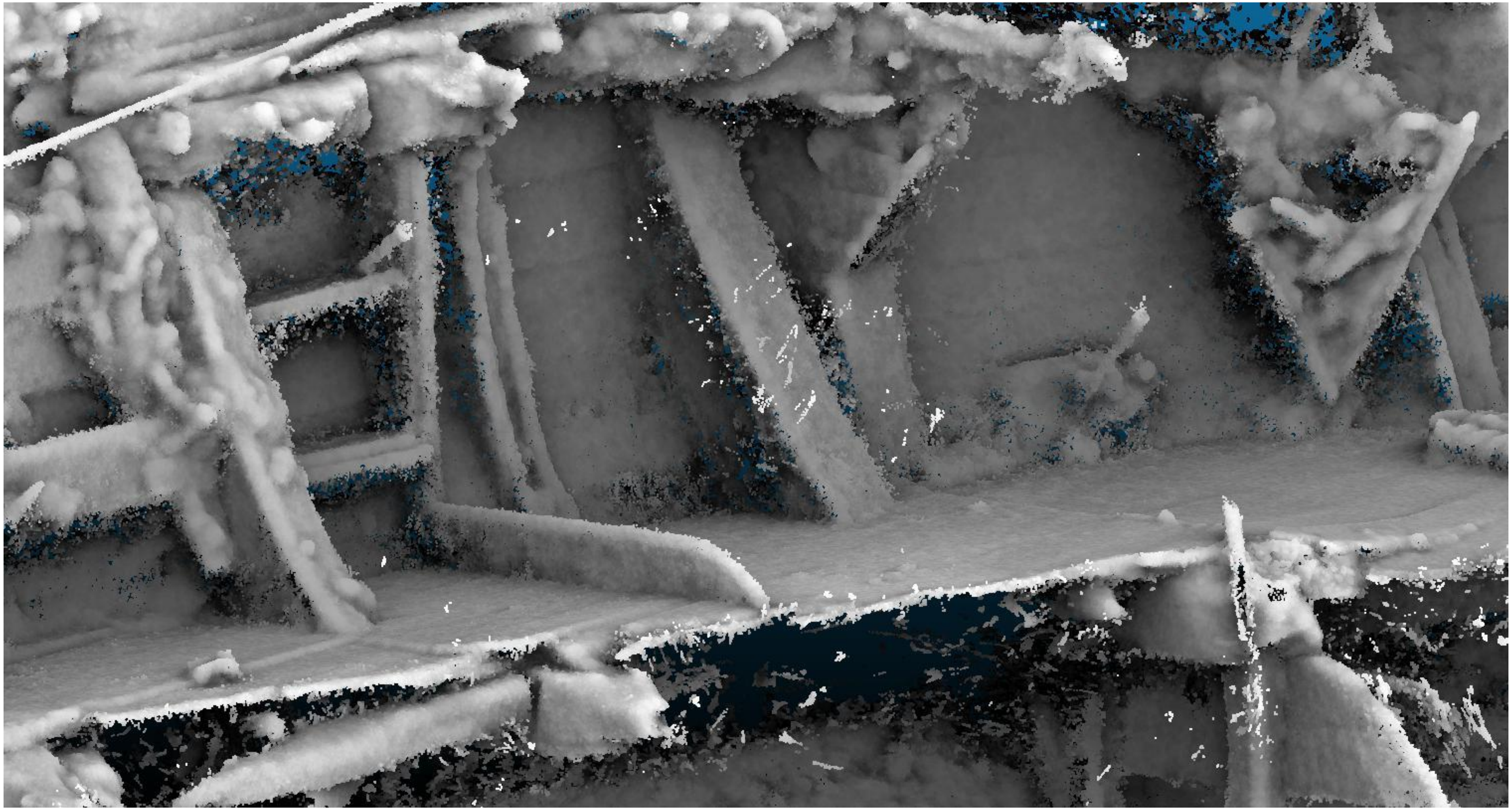


Figure 130. The figure shows close-up detail of a dense cloud of Trench 1, processed with PCV plug-in in Cloud Compare®. Set to the correct orientation, tilted on even keel.

Figure 131. The figure shows close-up detail of a dense cloud of Trench 1, processed with RGB in Cloud Compare®. Set to the correct orientation, tilted on even keel.

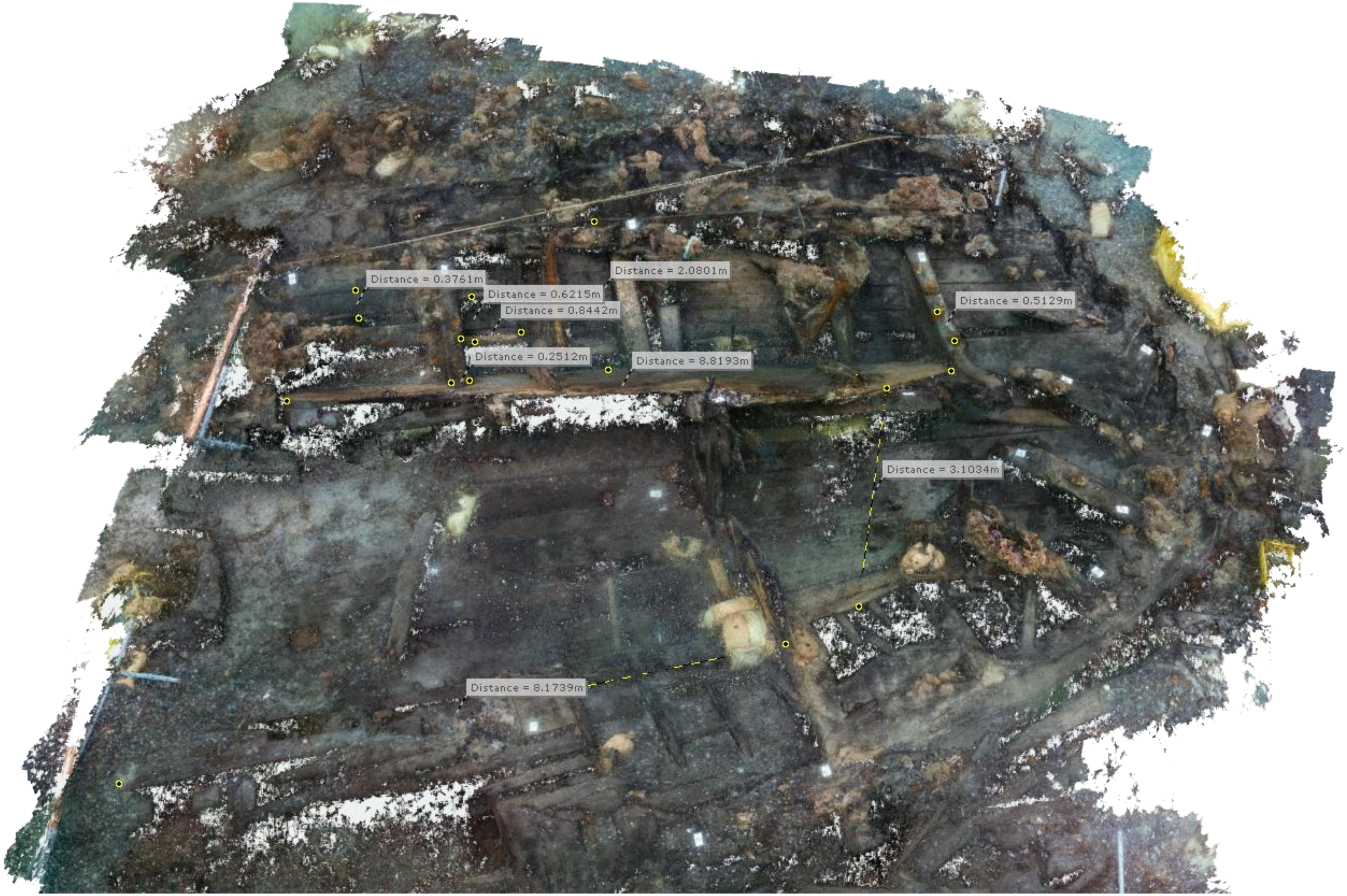


Figure 132. The figure shows a dense cloud of Trench 1, processed with FaroScene™, set to the correct orientation, tilted on even keel. Showing measurements of the structure.

Figure 133. The figure shows a close-up of a dense cloud of Trench 1, processed with FaroScene™, set to the correct orientation, tilted on even keel. Showing measurements of the structure.

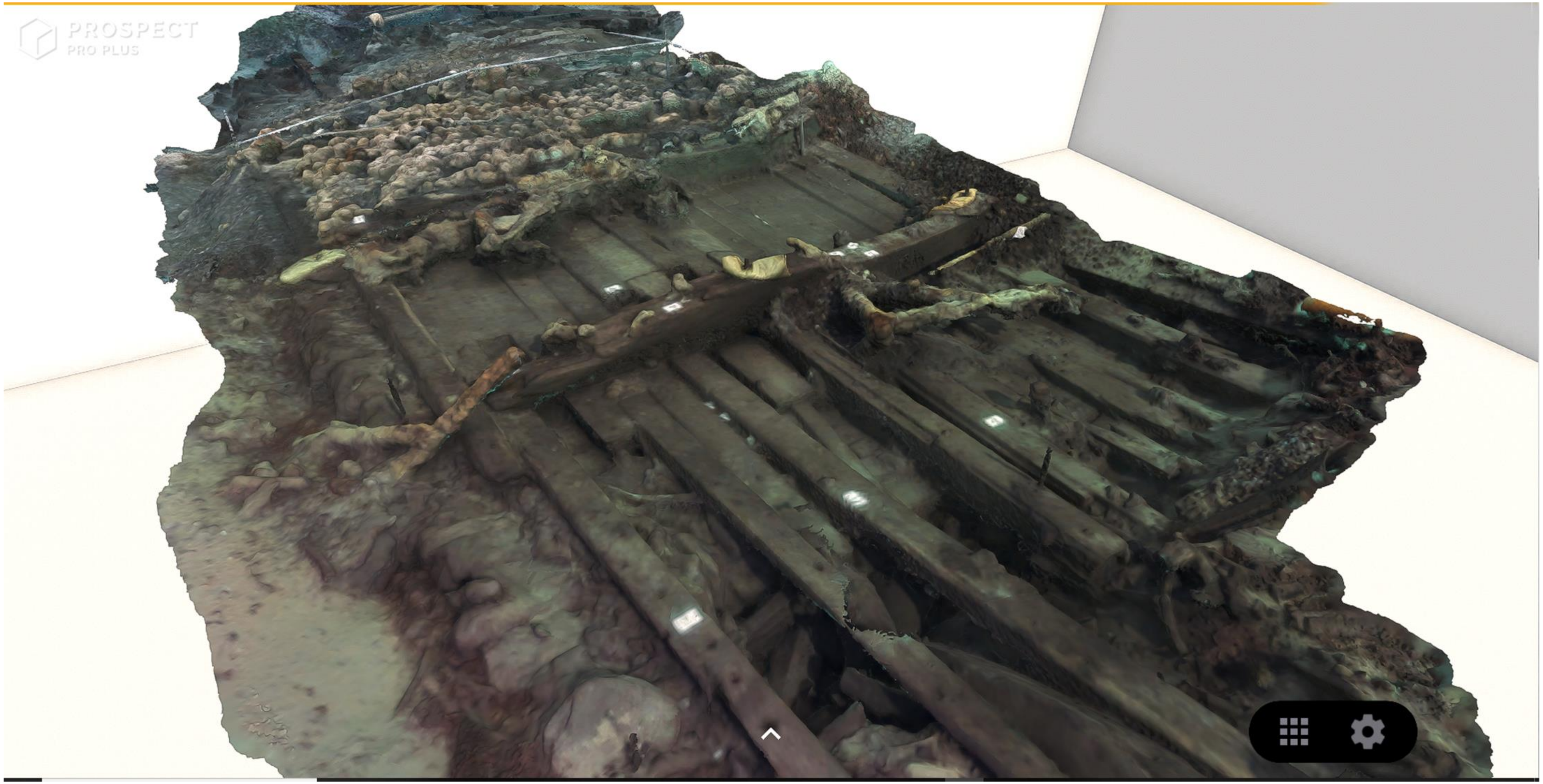


Figure 134. The figure shows Trench 2 in a VR environment. The figure was created by the author Prospect ProPlus®

Figure 135. The figure shows a double pulley block in a VR environment. The figure was created by the author Prospect ProPlus®

Figure 136. The figure shows HTC Vive ® VR headset used for public engagement during the NAS conference 2017, with Commander John Bingeman (MSDS Marine Ltd 2017)**.**

Bibliography

Artas Media. 2018. “The Wreck of the London.” *2017*. Retrieved April 22, 2018 (https://www.cloudtour.tv/london).

Astley, Amelia, Duncan Brown, Gill Campbell, Kathryn Dagless, David Dungworth, Julian Whitewright, and Duncan Brown. n.d. “The Stirling Castle, a 70-Gun Ship Lost in the Great Storm of 1703: Archaeological and Historical Archive, 1979-2009: Maritime Archaeology Trust Monograph Series (No. 4), within the British Archaeological Reports British Series.”

Astley, Amelia J. 2016. “The Taphonomy of Historic Shipwreck Sites.” University of southampton.

Beattie-Edwards, Mark. 2014. *Condition Assessment of the Holland No.5 Submarine*. Port.

Beattie-Edwards, Mark. 2017. *Norman’s Bay Wreck , Pevensey Bay , East Sussex Conservation Statement and Management Plan*. Portsmouth.

Beattie-Edwards, Mark, Peter Le Fevre, and Frank Fox. 2017. “The Norman’s Bay Shipwreck, East Sussex, UK: A Possible 17th-Century Dutch Ship from the Battle of Beachy Head.” *International Journal of Nautical Archaeology* (June 2006):1–23.

Beltrame, Carlo, Sauro Gelichi, and Igor Miholjek. 2014. *No Sveti Pavao Shipwreck: A 16th Century Venetian Merchantman from Mljet, Croatia*. Oxford: Oxbow Books.

Bentam, Charles. 1742a. “Model van Een Oostindiëvaarder Op Scheepskamelen.”

Bentam, Charles. 1742b. “VOC Retourschip.”

Berry, Jessica and Kevin Camidge. 2012. *Coronation. Geophysical Survey*.

BGS. 2018. “Marine Sediments. Offshore Products WMS/MapServer.” *WMS*. Retrieved February 22, 2018 (https://map.bgs.ac.uk/arcgis/services/Offshore/Products_WMS/MapServer/WmsServer).

Bingeman, John. 2010. *The First HMS Invincible (1747-58) Her Excavations (1980-1991)*. Oxford: Oxbow Books.

Bridge, Martin. 2011. “Resource Exploitation and Wood Mobility in Northern European Oak: Dendroprovenancing of Individual Timbers from the Mary Rose (1510/11-1545).” *International Journal of Nautical Archaeology* 40(2):417–23.

Camidge, K. 2007. *St Anthony Finds Record*. Penzance.

Camidge, Kevin. 2008. *Rill Cove Finds Record Project Report*.

Camidge, Kevin. 2013a. *Rill Cove. Desl-Based Assessment*.

Camidge, Kevin. 2013b. *Schiedam Prize. Desk Based Assessment*.

Camidge, Kevin. 2013c. *St Anthony Desk-Based Assessment*. Penzance.

Camidge, Kevin. 2017. *Colossus Wrecking Project*.

Camidge, Kevin, Gill Campbell, Damien Sanders, Polydora Baker, Jezz Davies, and Mags Felter. 2015. *HMS Colossus Investigation 2015*.

Camidge, Kevin, Tom Goskar, and Mark James. 2017. *Isles of Scilly Project Report*. Truro.

Camidge, Kevin and Charles Johns. 2014. *Royal Anne Galley Marine Environmental Assessment The Lizard, Cornwall. Phase 4 Monitoring : Initial Inspection and Monitoring*. Truro.

Camidge, Kevin and Charles Johns. 2016a. *Bartholomew Ledges , St Mary’s Sound , Isles of Scilly Conservation Statement & Management Plan Cornwall Archaeological Unit Bartholomew Ledges*. Truro.

Camidge, Kevin and Charles Johns. 2016b. *Royal Anne Galley , The Lizard , Cornwall Conservation Statement & Management*.
Camidge, Kevin and Charles Johns. 2017. *Tearing Ledge , Western Rocks , Isles of Scilly : Conservation Statement and Management Plan*. Penzance.
Camidge, Kevin, Charles Johns, and Ian Panter. 2011. *Royal Anne Galley Marine Environmental Assessment The Lizard, Cornwall Phase 3 Monitoring : Initial Inspection and Recovery*.
Camidge, Kevin, Charles Johns, and Phillip Rees. 2006. *Royal Anne Galley, Lizard Point, Cornwall. Marine Environmental Assessment Phase 1 Desk-Based Assessment*. Truro.
Camidge, Kevin, Charlie Johns, and Phillip Rees. 2009. *Royal Anne Galley, Lizard Point, Cornwall Desk-Based Assessment. Phase 2 Field Assessment Report*. Truro.
CCO. 2018. "Map Viewer and Data Catalogue." Retrieved February 21, 2018 (https://www.channelcoast.org/data_management/online_data_catalogue/).
Ch2m. 2007. *Strategic Environmental Assessment Scoping Report*. Leeds.
CISMAS. 2006. *The Search for Colossus: A Story of Wreck and Discovery.* Cornwall and Isles of Scilly Maritime Archaeology Society.
CISMAS. 2017. "Site of Tearing Ledge." *2017*. Retrieved April 17, 2018 (https://sketchfab.com/models/c2221cd67d004204b703b9ee9ef82cde).
CISMAS. 2018. "The Wreck of the Association." *2018*. Retrieved April 23, 2018 (https://skfb.ly/6vVXO).
Clarke, Richard, Martin Dean, Gillian Hutchinson, Sean McGrail, and Jane Squirrell. 1993. "Recent Work on the R. Hamble Wreck near Bursledon, Hampshire." *The International Journal of Nautical Archaeology* 22(1):21–44.
Connor, David W., James H. Allen, Neil Golding, L. Kerry, Louise M. Lieberknecht, Kate O. Northen, and Johnny B. Reker. 2004. *The Marine Habitat Classification for Britain And Ireland*. Peterborough.
Cotswold Archaeology Marine. 2014. *Cotswold Archaeology Marine NHPP 3A1 : Unknown Marine Assets & Landscapes Strategic Assessment of Submarines in English Waters*. Cirencester.
Cowan, Carrie. 2014. *Anne Pett Level, Nr Cliff End, Rye Bay, Rother, East Sussex. Conerervation Statemen & Managment Plan*. Swindon.
Craddock, P. T. and D. R. Hook. 1995. "Ingots from the Sea: A Coming of Age." *International Journal of Nautical Archaeology* 24(1):67–70.
Daykin-iliopoulos, Paris and Tom Cousins. 2013. *Gull Rock Wreck & Iona II Licensee Site Report*. Bournmouth.
Dobbs, Cris. 1995. "The Raising of the Mary-Rose - Archaeology and Salvage Combined." *Underwater Technology* 21(1):29–35.
Dresch, Patrick and Sally Evans. 2017. *Hanover Protected Wreck : Marine Assessment for Possible De-Designation*. Gloucestershire.
Van Duivenvorde, Wendy. 2015. *Dutch East India Company Shipbuilding: The Archaeological Study of Batavia and Other Seventeenth-Century VOC Ships*. Texas A&M University Press.
Dunkley, Mark. 2008. "Stirling Castle, Goodwin Sands, off Kent: Conservation Statement and Management Plan." (November):28.
Edina. 2018. "DigiMap." *2018*. Retrieved April 30, 2018 (https://digimap.edina.ac.uk/webhelp/marine/marinedigimaphelp.htm#terms_of_use/licence_agreement.htm).

EEA. 2018. “Data and Maps.” *20182*. Retrieved May 5, 2018 (https://www.eea.europa.eu/data-and-maps).
EMODnet. 2018. “Bathymetry. Understanding the Topography of the European Seas.” *EMODnet*. Retrieved February 15, 2018 (http://portal.emodnet-bathymetry.eu/).
Friel, I. 1993. “Henry V’s Grace Dieu and the Wreck in the R. Hamble near Bursledon, Hampshire.” *Ijna* 22(1):3.
Gawronski, J. H. G. 1990. “The Amsterdam Project.” *International Journal of Nautical Archaeology* 19(1):53–61.
Geography & Technology, Welsh Government. 2018. “Lle A Geoportal for Wales.” *2018*. Retrieved May 9, 2018 (http://lle.gov.wales/catalogue/item/CADWProtectedWrecks/?lang=en).
Hampshire & Wight Trust for Maritime. 2009. “Stirling Castle: Archive Summary Report, Final Report.” 43.
HE. 2017. “Protected Wreck Sites at Risk.” *2016*. Retrieved October 24, 2017 (https://historicengland.org.uk/advice/heritage-at-risk/archaeology/protected-wreck-sites-at-risk/).
HE. 2018a. “Download Listind Data.” *2017*. Retrieved February 1, 2018 (https://historicengland.org.uk/listing/the-list/data-downloads/).
HE. 2018b. “Periods List (Historic England).” *2018*. Retrieved May 5, 2018 (http://heritage-standards.org.uk/wp-content/uploads/2015/08/Periods-List-HE-FISH-WP.pdf).
Historic Environment. 2017. *Historic Environment Topic Paper. Enhancing the Historic Environment of the Isles of Scilly | 2017 The Local Plan 2015 – 2030*. St Mary’s.
Historic Environment Scotland. 2016. *Scotland’s Historic Marine Protected Areas 2016*. Edinbrugh.
Holt, Peter. 1997. “Site: Re-Surveying the Coronation Offshore Site (1691).” Retrieved April 20, 2018 (http://www.3hconsulting.com/sites/SitesCoronation.html).
Holt, Peter. 2010. “Geophysical Investigations of the Cattewater Wreck 1997-2007.” *3H Consulting* (August).
HWTMA. 2010. *Solent Marine Heritage Assets: Defining, Investigating. Monitoring and Reprting 2008-2011. Needles Protected Wreck Site Report*. Southampton.
Johns, Charles, Graeme Kirkham, Tom Cousins, and Dave Parham. 2015. *Rapid Coastal Zone Assessment Survey Phase One Desk-Based Assessment for South-West England (South Coast Dorset) 6673*. Truro.
Johns, Charles, Richard Larn, and B. P. Tapper. 2004. *Rapid Coastal Zone Assessmen for The Isles of Scilly*. Truro.
Johnston, David A. 2014. *Warship Hazardous Prize (1706) a Protected Wreck Site at Risk Case Study and Quantitative Analysis of Dynamic Seabed Movement and Rapid Site*. Vol. 1988. Southampton.
Larn, R. and B. Larn. 2002. *Shipwreck Index of the British Isles*. London: Lloyd’s Register.
Lavery, Brian. 1988. *The Royal Navy’s First Invincible: The Ship, the Wreck and the Recovery. Invincible Conservations (1744-1758)*. Invincible Conservations (1744-1758) Ltd.
Long, Dave. 2006. *BGS Detailed Explanation of Seabed Sediment Modified Folk Classification*. London.
Loughman, Emily. 2007. “What Is the Likelihood That the Tin Ingots from the Erme Ingot Site Are of British Bronze Age Date?” Bournmouth University.
Marsden, Peter. 1972. “The Wreck of the Dutch East Indiaman Amsterdam An Interim Report.” 73–96.

Marsden, Peter. 1974. *The Wreck of the Amsterdam*. London: Hutchinson & Co.
Marsden, Peter. 2003. *Sealed by Time: The Loss and Recovery of the Mary Rose*. edited by P. Marsden. Archaeology of the Mary Rose.
Marsden, Peter. 2007. *Guide to the Wreck Site of the "Amsterdam" 1749 at Hastings*. Hastings: the Shipwreck & Coastal Heritage Centre.
Marsden, Peter and David Lyon. 1977. "A Wreck Believed to Be the Warship Anne, Lost in 1690." *International Journal of Nautical Archaeology* 6(1):9–20.
Martin, Louise. 2008. *The Wreck of the Anne, Pett Level, East Sussex. Report on Geophysical Survey*. Portsmouth.
Mary Rose Museum. 2018. "Salvaging the Mary Rose – 1836-1843." *2014*. Retrieved March 10, 2018 (https://maryrose.org/blog/historical/museum-blogger/salvaging-the-mary-rose-1836-1843/).
MAST. 2017. "Coronation Shipwreck Virtual 3D Trail." Retrieved April 20, 2018 (http://www.thisismast.org/projects/coronation-3d-virtual-trail.html).
MAT. 2018. "HMT Arfon (1917), Stern and Propeller." *2017*. Retrieved April 23, 2018 (https://skfb.ly/WyHD).
MAT & Artas Media. 2018. "The Wreck of the HMT Arfon." *2017*. Retrieved April 23, 2018 (https://www.cloudtour.tv/arfon).
McBride, P. and R. Larn. 1999. *Admiral Shovell's Treasure: And Shipwreck in the Isles of Scilly*. Penryn: R. Booth Ltd & Troutbeck Press.
McCartney, Innes. 2002. *Lost Patrols: Submarine Wrecks of the English Channel*. Penzance: Periscope Publishing Ltd.
McGrail, Sean. 1993. "The Future of the Designated Wreck Site in the R. Hamble." *The International Journal of Nautical Archaeology* 22(1):45–51.
Mckee, Alexander. 1982. *How We Found the Mary Rose*. Souvenir Pree Ltd.
MOD. 2017. *The Protection of Military Remains Act 1986 (Designation of Vessels and Controlled Sites) Order 2017*. Vol. 1986. United Kingdom.
Morris, R. 1979. *HMS Colossus: The Story of the Salvage of the Hamilton Treasures*. London: Hutchinson & Co.
Morris, Roland. 1969. *Island Treasure: The Search for Sir Cloudesley Shovell's Flagship "Association."* London: Hutchinson & Co.
Mortlock, Beri. and Mark. Redknap. 1978. "The Cattewater Wreck, Plymouth, Devon::Preliminary Results of Recent Work." *The International Journal of Nautical Archaeology and Underwater Exploration* 7(3):195–204.
MSDS Marine Ltd. 2017. "RT @MSDSMarine." *17th Nov 2017*. Retrieved November 17, 2017 (https://twitter.com/msdsmarine?lang=en).
MSDS Marine Ltd. 2018. "Rooswijk 1740 Excavaiton." Retrieved April 6, 2018 (https://msdsmarine.com/rooswijk1740-excavation/).
MSDS Marine Ltd & Artas Media. 2018. "U8 Virtual Tour." *2017*. Retrieved March 23, 2018 (https://www.cloudtour.tv/u8/).
Muckelroy, Keith. 1978. *Maritime Archaeology*. Cambridge: Cambridge Univeristy Press.
Muckelroy, Keith. 1980. "Two Bronze Age Cargoes in British Waters." *Antiquity* 54(211):100–109.
Mynd, J., John Boydell, and Robert Short. 1747. "To the Honble Peter Warren...This Plate Is Most Humbly Dedicated...An Exact View of His Majesty's Ship Invincible, of 74 Guns, One of the Six French Men of War Taken the 3rd May 1747 by the British Fleet..."
NAS & 3Deep. n.d. "Holland 5 Submarine Diver Trail." *2017*. Retrieved April 22, 2018

(http://www.nauticalarchaeologysociety.org/content/holland-5-submarine-diver-trail).
National Geospatial-Intelligence Agency. 2018. "Prototype Global Shoreline Data (Satellite Derived High Water Line Data)." *NGA*. Retrieved February 14, 2018 (https://dnc.nga.mil/PrototypeGSD.php).
National Monuments. 2018. "National Monuments Service: Wreck Viewer." *2018*. Retrieved April 25, 2018 (https://dahg.maps.arcgis.com/apps/webappviewer/index.html?id=89e50518e5f4437abfa6284ff39fd640).
Nayling, Nigel. 2010. *The Swash Channel Wreck, Dorset Tree-Ring Analysis of Ship Timbers*. Lampeter.
NCEI. 2017. "Shoreline / Coastline Resources." *Information, National Centers for Environmental*. Retrieved November 8, 2017 (https://www.ngdc.noaa.gov/mgg/shorelines/).
Needham, Stuart, David Parham, and Catherine J. Frieman. 2013. *Claimed by the Sea: Salcombe, Langdon Bay, and Other Marine Finds of the Bronze Age*. CBA Resear. York: Council for British Archaeology.
Newton Charnock, John. n.d. "The Invincible French Ship of War Mounting 74 Guns, Captured from France, May 3d 1747, by Vice Admiral Anson & Rear Admiral Vernon."
OESEA3. 2014. *Offshore Energy SEA 3: Appendix 1 Environmental Baseline. Appendix 1l: Cultural Heritage*. London.
Oldham, N., M. Palmer, and J. Tyson. 1993. "The Erme Estuary, Devon, Historic Wreck Site, 1991–3." *International Journal of Nautical Archaeology* 22(4):323–30.
Open Data NI. 2018. "Protected Wrecks." *2017*. Retrieved May 9, 2018 (https://www.opendatani.gov.uk/dataset/protected-wreck-sites/resource/1c0cf393-fda4-45d1-a763-a6ce34235cc8).
Open Data Unit. 2018. "The Real Map of Ireland." *2018*. Retrieved April 25, 2018 (https://data.gov.ie/dataset/the-real-map-of-ireland).
Ortiz-Vázquez, Rodrigo. 2015. "The Maritime Archaeology of Alum Bay: Two Shipwrecks on the North-West Coast of the Isle of Wight, England (The Maritime Archaeology Trust, British Archaeological Reports, British Series, BAR Series 608, Monograph Series No. 2)." *Journal of Maritime Archaeology* 10(2):181–83.
Owen, Norman. 1988. "HMS Hazardous Wrecked 1706. Pre-Disturbance Survey Report 1987." *International Journal of Nautical Archaeology* 17(4):285–93.
Owen, Norman. 1991. "Hazardous 1990-1991 Interim Report." *International Journal of Nautical Archaeology* 20(4):325–34.
Palma, Paola and Dave Parham. 2006. *Swash Channel Wreck; 2006 Season Report*. Bournmouth.
Palma, Paola and Dave Parham. 2007. *Swash Channel Wreck; 2006 Season Report*. Bournmouth.
Parham, David. 2005. "The Studland Bay Wreck." in *Society for Historical Archaeology Annual Conference. York (UK)*. York: Bournemouth University.
Parham, David. 2010. *Swash Cannel Designated Wreck Site Project Design. Mitigation of a High Risk Projected Wreck.* Bournmouth.
Parham, David. 2011. "The Swash Channel Wreck." Pp. 103–6 in *ACUA Underwater Archaeology Proceedings*, edited by F. Castro and L. Thomas. Advisory Council on Underwater Archaeology.
Parham, David, Elizabeth Rundell, and Pieter van der Merwe. 2013. "A Late-18th-Century

Merchantman Wrecked in the South." *International Journal of Nautical Archaelogy* (42):137–49.
Parham, David, Chris Underwood, and Ruth Rhynas Brown. 2013. "British Postal Packet Hanover, 1757: Salvage and Archaeology." *International Journal of Nautical Archaeology* 42(2):403–12.
Parry, M. E. V, K. L. Howell, B. E. Narayanaswamy, B. J. Bett, D. O. B. Jones, D. J. Hughes, N. Piechaud, T. D. Nickell, H. Ellwood, N. Askew, C. Jenkins, and E. Manca. 2015. *A Deep-Sea Section for the Marine Habitat Classification of Britain and Ireland V15.03*. Peterborough.
PAS. 2015. *Assessing, Monitoring and Recording a Designated Wreck for Vulnerability: HMS Invincible*. Southampton.
PAS. 2017. *Multi-Beam Surveys of the Designated Wrecks on the Goodwin Sands and the Downs*. Southampton.
PAS. 2018. "The London Excavations." *2017*. Retrieved April 22, 2018 (https://pascoe-archaeology.com/portfolio/the-london/).
Pascoe, Daniel, Mark Mavrogordato, and Angela Middleton. 2014. "A Chain Pump Recovered from the Wreck of the Warship Northumberland (1703)." *International Journal of Nautical Archaeology* n/a-n/a.
Pascoe, Daniel and Robert Peacock. 2015. "The Wreck of the Warship Northumberland on the Goodwin Sands, England, 1703: An Interim Report." *International Journal of Nautical Archaeology* 44(1):132–44.
Pink, Fiona. 2016. "Rapid Coastal Zone Assessment Survey for South West England - South Devon Coast: Results of Phase 1, Component 2 Desk-Based Assessment." (January).
Plets, Ruth M. K., Justin K. Dix, Jonathan Adams, Jonathan M. Bull, Timothy J. Henstock, Martin Gutowski, and Angus I. Best. 2009. "The Use of a High-Resolution 3D Chirp Sub-Bottom Profiler for the Reconstruction of the Shallow Water Archaeological Site of the Grace Dieu (1439), River Hamble, UK." *Journal of Archaeological Science* 36(2):408–18.
Plets, Ruth M. K., Justin K. Dix, and Angus I. Best. 2008. "Mapping of the Buried Yarmouth Roads Wreck, Isle of Wight, UK, Using a Chirp Sub-Bottom Profiler." *International Journal of Nautical Archaeology* 37(2):360–73.
Quinn, R., J. M. Bull, and J. K. Dix. 1997. "Buried Scour Marks as Indicators of Palaeo-Current Direction at the Mary Rose Wreck Site." *Marine Geology* 140(3–4):405–13.
Quinn, R., J. M. Bull, J. K. Dix, and J. R. Adams. 1997. "The Mary Rose Site-Geophysical Evidence for Paleo-Scour Marks." *The International Journal of Nautical Archaeology* 26(1):3–16.
Quinn, Rory, Jonathan Adams, Justin Dix, and Jonathan Bull. 1998. "The Invincible (1758) Site-an Integrated Geophysical Assessment." *IJNA* 27.2:126–38.
Redknap, M. 1997. "The Cattewater Wreck: A Contribution to 16th Century Maritime Archaeology,." in *Postmedieval Boat and Ship Archaeology BAR International Series 256*, edited by C. O. Cederlund. Oxford: BAR.
Satchell, Julie and Julian Whitewright. 2014. *The Maritime Archaeology of Alum Bay*. Oxford: British Archaeology Reports.
Scott, Samuel. n.d. "Lord Anson's Victory off Cape Finisterre, 3 May 1747."
Simpson, K., H. Hall, R. Davis, and R. Lam. 1977. "An Early 17th Century Wreck near Rill Cove, Kynance, Cornwall An Interim Report." *International Journal of Nautical Archaeology* 6(2):163–66.
Storck, Abraham. 1699. "Het Eiland Onrust Bij Batavia."

The Crown Estate. 1986. "Protection of Military Cultural Heritage Act 1986." 3(i).
Thomsen, Mikkel H. and Keith Jarvis. 2000. "The Studland Bay Wreck, Dorset, UK: Hull Analysis." *International Journal of Nautical Archaeology* 29(1):69–85.
Tomalin, David J., Paul Simpson, and John M. Bingeman. 2000. "Excavation versus Sustainability in Situ: A Conclusion on 25 Years of Archaeological Investigations at Goose Rock, a Designated Historic Wreck-Site at the Needles, Isle of Wight, England." *International Journal of Nautical Archaeology* 3–42.
Tyson, Jim and Mick Palmer. 2013. *Salcombe/Moor Sand Sites 2013 End of Season Report*.
UKHO. 2018. "UKHO Inspire Portal & Bathymetric DAC." *2018*. Retrieved April 29, 2018 (http://aws2.caris.com/ukho/mapViewer/map.action).
Uknown. 1725. "Gezicht Op Het Oost-Indisch Zeemagazijn En de VOC-Scheepswerf Op Oostenburg Te Amsterdam."
Uknown. n.d. "Superb (Captured 1710)."
WA. 2007. *Rooswijk, Goodwin Sands*. Salisbury.
Wessex. 2009. *Gull Rock, Off Lunday Island, North Devon*. Salisbury.
Wessex Archaeology. 2003a. *Bonhomme Richard, Filey Bay, North Yorkshire. Designated Site Assessment: Full Report.* Salisbury.
Wessex Archaeology. 2003b. "Stirling Castle, Designated Historic Wreck Site, Desk-Based Assessment." (287786).
Wessex Archaeology. 2004a. *Coronation Offshore, Penlee Point Plymouth. Sedignated Site Assessment: Full Report*. Salisbury.
Wessex Archaeology. 2004b. *North Edinburgh Channel Dredging Disposal Area. Archaeological Assessment Technical Report*. Salisbury.
Wessex Archaeology. 2005a. *Iona II, Lundy*. Salisbury.
Wessex Archaeology. 2005b. *Loe Bar, The Lizard, Cornwall. Designated Site Assessment: Full Report*. Salisbury.
Wessex Archaeology. 2005c. *Royal Anne, Lizard Point, Cornwall. Designated Site Sessessment: Full Report*. Salisbury.
Wessex Archaeology. 2006a. *Dunwich Bank, Suffolk. Designated Site Assessment*. Salisbury.
Wessex Archaeology. 2006b. *HMS/m A1, Bracklesham Bay*. Salisbury.
Wessex Archaeology. 2006c. *Restoration, Goodwin Sands.Designated Site Assessment: Archaeological Report*. Salisbury.
Wessex Archaeology. 2006d. *Salcombe Cannon Site, Devon*. Salisbury.
Wessex Archaeology. 2007. *St Anthony. Designated Site Assessment*. Salisbury.
Wessex Archaeology. 2008. *Tearing Ledge, Isles of Scilly. Designated Site Assessment: Archaeological Report*. Salisbury.
Wessex Archaeology. 2009. *HMS/m Holland No.5 English Channel. Designated Site Assessment. Archaeological Report.*
Wessex Archaeology. 2011a. *19th Century Merchant Sailing Ship Off Thorness Bay, Isle of Wight*. Salisbury.
Wessex Archaeology. 2011b. *Unknown Site GAD 8, the Downs, Kent*. Salisbury.
Wessex Archaeology. 2013. *Ships and Boats : Prehistory to 1840. Strategic Desk-Based Assessment*. Salisbury.
Wessex Archaeology. 2015. *Archaeological Services in Relation to Marine Protection Off South Varne Buoy , English Channel*. Salisbury.
Wessex Archaeology. 2017. *UC-70, off Whitby, North Yorkshire, Field Assessment Report for Historic England*. Salisbury.

Wessex Archaeology. 2018a. “Chesil Beach Cannon Site.” *2017*. Retrieved April 23, 2018 (https://skfb.ly/6tHEn).
Wessex Archaeology. 2018b. “Mystery Chesil Beach Shipwreck Designated Following Wessex Archaeology Fieldwork.” *2017*. Retrieved April 23, 2018 (https://www.wessexarch.co.uk/news/mystery-chesil-beach-shipwreck-designated-following-wessex-archaeology-fieldwork).
Wessex Archaeology. 2018c. “West Bay.” *2008*. Retrieved April 22, 2018 (https://www.wessexarch.co.uk/news/west-bay).
Whitwright, Julian and Julie Satchell. 2014. *Alum Bay Marine Archaeological Investigations. Managment Report.* Southampton.
WHPPG. 2018. “The Hazardous Project.” Retrieved April 6, 2018 (http://hazardousproject.info/history1.html).