

Rapid Archaeological Site Survey and Evaluation
RASSE



**Innovative Approaches to Rapid Archaeological Site
Surveying and Evaluation in the Marine Environment and
Transitional Zones**

**PROJECT DESIGN
For English Heritage**

Project Number 3837

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Forward

- i. This revised Project Design (PD) by the University of St Andrews for the project entitled “Innovative Approaches to Rapid Archaeological Site Surveying and Evaluation in the Marine Environment and Transitional Zones” has been prepared following the initial submission of a Project Design following a Project Outline (ref 3837) submitted by the University of St Andrews in June, 2004.
- ii. Considerations have been made to comments supplied by English Heritage Project Officer Helen Keeley on the original PD together with considerations to discussion with EH staff and discussion with other ALSF project partners both during a meeting held to discuss various ALSF projects at EH Fort Cumberland on 20 July, 2004 and subsequent to this.
- iii. This module therefore represents the methodological part of the initial submission but not that for mapping through the Transition Zone. A separate module will be submitted for this after further discussions with EH and ALSF partners.

1 INTRODUCTION

The principle aim of this project is to exploit the potential of geophysical, remote survey equipment to allow rapid detailed investigation of submerged archaeological sites and their immediate surroundings for enhanced understanding of the environmental settings in which the sites are located. Through the use of rapid mapping techniques, it is proposed that quantifiable environmental changes over time can be cost-effectively monitored on sites in order that the potential impact of anthropogenic activity such as aggregate extraction and natural cycles of change can be assessed more accurately. A secondary aim is establish the optimum configuration of acoustic instruments using a combination of backscatter (sidescan) and bathymetry information to provide the best data for informed management decision making. This project will go beyond currently available techniques and utilise a number of new and innovative approaches for investigation of maritime archaeological sites.

It is proposed to test the acoustic methods on three sites. The first is an artificial test site where a selection of high resolution geophysical equipment will be deployed. The second is a complex wreck site (the *Stirling Castle*) where considerable environmental change has been noted but which has been difficult to quantify through diver observations or general geophysical surveys. The third site is one in deeper water identified by Wessex Archaeology as an example of the future trend in Aggregate Extraction.

Geophysical surveys are routinely used for commercial and research applications in biological, environmental, hydrographical, and military projects. These exploit a wide range of sonar technology, including single beam echo sounders and acoustic ground discrimination systems, sidescan and multibeam sonar. These systems have only recently been applied to disciplined maritime archaeological investigations. Innovative applications of multibeam and ground discrimination systems by researchers at the University of St Andrews (Bates and Byham, 2001; Murray et al, 2004; Dean and Frazer, 2004) over the last few years has indicated the potential that these approaches can provide with important new data sets which further the understanding of the general environmental impact, but more specifically the potential effect of aggregate extraction, on archaeological sites in the sea.

The combination of ultra high resolution acoustic data with ground discrimination data allows rapid and accurate modelling of exposed archaeological material on the seabed in addition to the characterisation and nature of the surrounding sediments, which are themselves fundamental in the long term preservation of such material. Furthermore, recent advances in acoustic processing techniques by engineers at the University of Edinburgh and AMS (BAE) will afford new insights into the acoustic data that could offer not only enhanced discrimination of archaeological material but should also significantly increase the efficiency of site investigation.

These new techniques will be tested as such information is critical for the long-term management. The limits of these new techniques will be explored to provide crucial information for the long-term management of the submerged

archaeological resource in UK coastal waters where there is increasing pressure from aggregate extraction as well as other commercial and recreational activities.

This Project Design outlines methods and costs for achieving the following objectives:

- 1 Documentation and Evaluation of Historical Records** – determining the amount of environmental change that has been recorded from past records on the archaeological sites including traditional observation and recordings made using more modern geophysical techniques
- 2 Geophysical Equipment Appraisal** – the use of advanced geophysical techniques for environmental characterisation and monitoring around wreck sites, and the application of high resolution acoustics to submerged archaeological sites including feature and object characterisation on these sites
- 3 Development of Enhanced Geophysical Processing Techniques** – new techniques for the quantitative processing of geophysical data in terms of artifact signature recognition and environmental information within the context of archaeological heritage will be implemented
- 4 Characterising Environmental Setting and Environmental Change** – geological, geophysical, and biological information will be documented in order to establish environmental character and environmental change on maritime historical sites with particular reference to the difference between natural (climatic) and anthropogenic (aggregate extraction) impacts
- 5 Public Dissemination/Outreach** – to work with national heritage services, local Museum Services in providing information from the project to enhance community awareness of, and accessibility to, maritime archaeology

In preparation of this proposal, the University of St Andrews has considered the strategic priorities set out by English Heritage in Implementation Plan for Exploring our Past, EoP98 (1998) and Taking to the Water (Roberts and Trow, 2002), Power of Place: the Future of the Historic Environment (English Heritage, 2000) and The Historic Environment: a Force for our Future (DCMS, 2001). The proposed project will commence on 1 November 2004 and be completed by 1 October 2006.

2 PROJECT BACKGROUND

2.1 Project area

Within the Territorial Waters of the UK numerous maritime sites of archaeological interest have been discovered over the last four decades that represent a unique, and to a large extent un-quantified, cultural resource. In these near shore areas increasing exploitation of natural resources such as aggregate is resulting in an ever-increasing number of discoveries of archaeological significance.

In order to make appropriate management decisions about the archaeology it is necessary to identify any impacts that may lead to the deterioration or destabilisation of archaeological sites underwater. Full archaeological investigation of every site discovered is not economically viable and therefore strategies need to be developed urgently for the rapid assessment and effective management of new sites. Currently only a small proportion of the 40,000 plus documented seabed obstructions recorded in the various Maritime Sites and Monuments Records have been investigated archaeologically. Of these sites less than 60 have been recognised as being of sufficient importance to be designated under the Protection of Wrecks Act 1973.

2.2 Previous Work

2.2.1 Aggregate Extraction and Maritime Archaeology

Rapid site assessment is an essential component for ensuring sustainable, environmentally sensitive aggregate extraction. Dredging practices need to meet a number of codes of practice and adhere to legislation designed to safeguard archaeological sites. Best practice includes pre-survey desk based studies of potential sites, pre-survey regional field investigation of potential sites using various remote sensing (geophysical) and ground truth methods in order to establish baseline conditions for the area, setting up of exclusion zones around potential sites and finally post-dredging regional impact assessment. Some of the tools used to assess the dredge resource, such as sidescan sonar, can often provide information for archaeological assessment if processed using appropriate methods but to date these methods have not been tailored to archaeological investigations. No survey software exists to date that uses characteristics of archaeological sites to aid in interpreting the sonar records. Furthermore, if the long term stability of a site is to be evaluated by both EH and the local curators then additional information on the seabed change must be surveyed at each site. This information includes the site environmental setting, the nature and distribution of sediment, the movement of sediment, the biological stabilising cover (the local biology). With the rise in total near shore and offshore aggregate extraction over the last decade (Appendix A) the pressures on cultural material preservation have increased. It is thus now critical that precise and effective methods for rapid site evaluation are developed. Furthermore, with the increased pressure on the nearshore, transition zone from rapidly changing climate, it is of more pressing urgency than ever before that we are able to rapidly evaluate changes caused by local anthropogenic activity in comparison to the

environmental changes from climate such as sediment erosion and re-distribution.

2.2.2 Rapid Archaeological Site Survey and Environmental Evaluation

It has recently been shown that in order to formulate management strategies in coastal waters, adoption of investigation technologies currently used in other marine survey industries is necessary to fully understand the environmental parameters that influence submerged cultural material *in-situ*. These technologies include ultra high resolution, full coverage 3D bathymetry (Dean & Frazer, 2004), single beam acoustic classification using acoustic ground discrimination sonar – AGDS (Lawrence and Bates, 2002), classified sidescan seafloor object recognition (Quinn *et al*, forthcoming) and acoustic-based sediment identification (Bates and Moore, 2002).

A range of acoustic methods have been used for the investigation of maritime archaeological sites, and the considerable potential of sidescan sonar in particular has been realised over the last two decades (Rao, 1988; Redknap, 1990; Quinn *et al*, forthcoming). The distribution of sediment types determined from sidescan sonar images has been recognised as having important archaeological implications (Duck, 1995). The effect on the acoustic response of the seabed (altered backscatter levels) from buried archaeological material has also been recognised (Fish and Carr, 1990; Fish and Carr, 2001; Quinn *et al*, forthcoming). Chirp sub-bottom systems have been tested for non-invasive, high-resolution investigations of sites of maritime archaeological interest (Quinn *et al.*, 1997) and in addition, bathymetric data from phase-based and multibeam sonar has important archaeological implications (Momber & Geen, 2000; Dean & Frazer 2004). Despite the individual application of advanced sonar techniques, no definitive strategy has been developed for their use in archaeological site mapping and monitoring. This project will provide key data for providing this strategy subsequent to the evaluation of the innovative techniques outlined.

The potential use of multibeam sonar for the mapping of submerged archaeological sites is clearly demonstrated in Figures 1 and 2. The images represent data collected using a Reson SeaBat 8125 system. The utility of multibeam for archaeological site surveys where wreck sites contain upstanding material has also been demonstrated within the ALSF programme by Wessex Archaeology (Wrecks on the Seabed, Year 2 Report). The conclusion from this work was that while multibeam does provide absolute positioning of material, two survey methods are needed for most site evaluations. A broad scale survey is necessary where information is merged for the whole site and this is supplemented by a very high detail survey at slow boat survey speed over the wreck site for recognition of key features. The project further concluded that while backscatter information is available from the multibeam survey for pseudo-sidescan images it requires considerable operator experience and post-processing to utilise and is therefore not in the near future of as much use as the true sidescan images. This work did not take into account the critical relationship between definition and the grazing angle of the acoustic beams relative to the seabed identified by previous St Andrews research (Quinn *et al*, Forthcoming). However, the

Year 2 Report does point to research development work currently being undertaken in the US for future use of multibeam data. Through international collaboration between the University of St Andrews and Dr Larry Mayer (University of New Hampshire), and UK collaboration this work is currently being conducted between the University of St Andrews, Edinburgh University and Oxford University. It is the use of these new methods that is the main thrust of this proposal that goes beyond Wrecks on the Seabed.

2.3 Relation to National Objectives and Priorities

Guidance on national priorities for maritime archaeology are outlined in Exploring our Past 1998 Implementation Plan. This document sets out the goals and programmes that provide the context for specific maritime investigative projects. With respect to maritime archaeology, further guidance has been given in Taking to the Water (Roberts and Trow, 2002) who recognised that the offshore zone is particularly poorly studied, especially in vulnerable areas where commercial operations such as mineral extraction are undertaken. Furthermore, the project will also help address the relatively poor development of research frameworks within marine archaeology.

Taking to the Water identified remote methods (geophysics) as a priority that needs to be investigated for developers in identifying, mapping and mitigating the impact to maritime archaeology. With increasing use of near shore and offshore zones for commercial mineral extraction, it is vital that the full capabilities of rapid, remote sensing methods such as offered by geophysical tools are therefore fully developed. This project aims to further advance not only the methods but their use across a wide spectrum of potential investigators.

The project will also help address technologies and methodologies for monitoring of changes in environmentally sensitive areas designated under European legislation such as Marine Special Areas of Conservation (marine SAC's) following national and European priorities under the 1992 Habitat Directive. This is of particular importance as it is seen as vital for the marine community to develop a multidisciplinary approach for offshore investigations with a holistic view of the environment. An holistic approach lies at the heart of this project as it is only through a comprehensive evaluation of all environmental aspects associated with maritime archaeological sites that the sites can be managed on a long term basis. The project will directly address maritime heritage issues with newly developed techniques and so will add to knowledge of submerged archaeological sites and maritime archaeological site practice.

2.4 Relation to ALSF Objectives and other ALSF Projects

Developing the capacity to manage aggregate extraction landscapes in the future is at the core of the objectives for the ALSF programme. Specifically, Objective 2 identifies the acquisition of baseline information and characterisation of resources as a priority. This proposal will provide information with regard to maritime sites where there is upstanding wreck material through the use of new tools for remote sensing (geophysical)

surveying. Management of archaeological maritime resources requires a knowledge of change within a landscape and this proposal aims to address this through methods for measuring environmental change at sites using key observations. Key observations include not only the amount of change but also the scale at which the change can be measured. Change is an ever present part of our evolving environment and thus in assessing the local impacts of change it is vital that an appreciation is made of the Quaternary record that includes key information on past conditions. In a maritime nation the most dramatic manifestations of change have happened from the coast line transition zone out across the continental shelf area. All the maritime ALSF projects focus on this area as much of the future aggregate extraction will take place here in water depths out to 30m and beyond.

In summary, the following key points can be made concerning how national maritime archaeological research goals can be addressed within the ALSF programme:

- Maritime archaeological sites are often difficult to monitor and in highly vulnerable locations that need constant evaluation for long term safe guarding.
- Due to this difficulty and the expense of surveying maritime sites, limited studies will only ever be possible therefore the most effective techniques must be available to ensure that the most important sites are evaluated.
- Quantitative rapid methods of measuring baselines, present and future change are vital for providing important information for the long term management of maritime sites.
- The interpretive potential of any archaeological material depends upon understanding of depositional and post-depositional processes that have affected it.

This project has significant links to other previous ALSF projects and a number of current ALSF projects. In particular it will follow closely on from the methodological stages of the *Wrecks on the Seabed, Assessment, Evaluation and Recording, Wessex Archaeology* project where a number of geophysical techniques were tested at various wreck sites in order to establish the potential of the techniques. This project aims to go beyond those findings by testing new methods for quantitative data processing leading to new tools for survey companies, the aggregate industry and curatorial managers for the rapid assessment of archaeological sites.

2.6 Investigation Sites

The range of significant maritime archaeological sites in the Territorial Waters of the UK varies from the Middle Bronze Age sites to 20th century sites. In order to fully evaluate the proposed survey methodologies for archaeological site characterisation and assessment of impact from aggregate extraction, and also to establish the best practice for these methods, three test sites have been chosen. One site will be located in a shallow protected area of water in Plymouth Sound where an array of test features, objects and materials will be placed on the seabed building on the experience of the sidescan sonar

experiment conducted jointly by the Universities of St Andrews and Ulster in 2002 (Quinn *et al*, forthcoming). The two other sites will be surveyed twice during the project to establish rates of environmental change over field seasons. A review of historical bathymetric and other environmental data associated with each site will be undertaken to help evaluate the potential change on the sites from nearby aggregate extraction and close collaboration will be maintained with other ALSF projects of relevance (in particular with those of Wessex Archaeology and with SOC). The *Stirling Castle* on the Goodwin Sands has been chosen as a typical wreck site that has a significant amount of remote sensing data acquired over the past 5 years that indicates that the site is one of rapidly changing conditions. The other test site is located in the Hastings Shingle Bank Area containing the wreck of the *Thomas Lawrence*. This site has been chosen as it represents an area where future anticipated aggregate extraction. The site has also been chosen as it is one where Wessex Archaeology have been commissioned to survey as part of Wrecks on the Sea Bed R2 (ALSF Round 2 Project) and thus a joint survey will greatly benefit ALSF programme through close integration of findings.

3 PROJECT AIMS AND OBJECTIVES

3.0.1 The main project aim is to further develop rapid quantitative assessment methods for submerged archaeological sites through the use of advanced geophysical technologies.

The project aims and objectives have been developed in response to a number of factors. These include the need to build on recent and on-going projects within the area and in particular to extend the work conducted by a number of units during Round 1 ALSF by exploiting the complimentary expertise and research experience of the authors and their Project Partners. The project thus aims to work closely with teams from the University of Southampton and Wessex Archaeology. Furthermore the project aims to assimilate past knowledge derived from observations and collections made in former marine geological and archaeological investigations and from previous aggregate extraction reports. In particular the project is to be developed with the clear objective of providing improved temporal and environmental assessment methods of key archaeological significance. The objectives have been sub-divided into three main areas:

- Academic.
- Curatorial.
- Dissemination.

The project objectives address issues of direct relevance to the aggregate industry and archaeological curators, as well as the academic audience. The academic objectives are relevant at regional, national as well as international levels and complement other major projects such as the *Wrecks on the Seabed, Assessment, Evaluation and Recording, Wessex Archaeology; Submerged Palaeo-Arun & Solent Rivers: Reconstruction of Prehistoric Landscapes Pt 1, Imperial College; Multi-Beam sonar on wrecks, Wessex Archaeology; Designated Historic Wreck Sites, Protection of Wrecks Act 1973 Programme.*

3.1 Academic Objectives

3.1.1 *Environmental Setting Mapping Techniques (Objective 1)*

To refine knowledge and understanding of the techniques for mapping the environmental context (the sedimentological and broader environmental including biological setting) of a wreck site, in particular in sites of medium to coarse sediment material at or near the sea bed surface.

3.1.2 *Environmental and Palaeo-environmental Setting (Objective 2)*

To determine the key environmental features and environmental stability surrounding sites of submerged archaeology.

3.1.3 *Environmental Change (Objective 3)*

To investigate the rate of environmental change and indicate potential causes (natural and anthropogenic) of change around maritime archaeological sites.

3.1.4 Development of methodologies (Objective 4) to maximise the archaeological and environmental detail obtained by high resolution sonar.

3.1.5 Enhanced methods for Processing Remote Sensing Data (Objective 5)
To refine remote classification methods for mapping the environmental setting, and identifying the material within, submerged archaeological sites.

3.2 Curatorial and Management Objectives

3.2.1 Environmental Distribution (Objective 6)

To map the distribution of environmental factors surrounding key maritime archaeological sites of significance. Providing critical information on environmental factors to county planners, members of the aggregate industry, heritage managers and academics will enable informed decision to be made on the condition on the sites.

3.2.2 Environmental Change (Objective 7)

To assess the previous and current change in environmental conditions surrounding key maritime sites in order to provide vital information on the long term stability of sites.

3.2.3 Environmental Future Scenario (Objective 8)

To provide appropriate information for the modelling of future changes to wreck sites for the long term management of the sites and the potential impact that future aggregate extraction might have on them. The results of these aspects of the project will be passed to the relevant curatorial and management authorities in the study region for cross-referencing with mineral extraction plans and for the *Stirling Castle* will be provided to Dr Justin Dix for modelling within the SOC ALSF project.

3.2.4 Development (Objective 9)

To provide enhanced tools for the rapid mapping and quantitative, automated monitoring of maritime archaeological sites and their surrounding environment.

3.3 Dissemination Objectives

3.3.1 Dissemination of Data to EH and ALSF Partners (Objective 10)

To share data, results, conclusions and recommendations within English Heritage and the ALSF Partner projects through meetings, reports and digital information.

3.3.2 Dissemination of Results and Recommendations to Curators (Objective 11)

To communicate the results, findings and recommendations to local curators and prepare guidelines on the use of the enhanced geophysical techniques for contract surveyors and wider curatorial staff.

3.3.3 Dissemination of Results to Public Audience (Objective 12)

A Web site will be created for the dissemination of results from the project. The web site will contain information on the sites, the techniques used and the results of monitoring over the course of the project.

3.3.4 *Dissemination of Results to Academic Audience (Objective 13)*

Publication of the results in academic, peer reviewed Journals and at national and international conferences on maritime archaeology.

4 METHOD STATEMENT

4.1 Seabed Character

There are many factors that influence the character of the seabed around a submerged archaeological site each of which have their part to play in the overall site formation process. These factors include the location of the site itself and the physical, chemical and biological environment surrounding it. At archaeological sites, environmental properties such as sediment type, can also determine the preservation potential of the cultural material (Muckelroy, 1977). Advances have been made in understanding the deterioration characteristics of various types of submerged archaeological material on shipwreck sites due to these factors (Gregory, 1995; Macleod, 1998). Any process that alters or controls the physical properties of sediment will also change the acoustic properties of that sediment (Richardson and Briggs, 1993) and thus the presence of archaeological material will affect the acoustic properties of sediment both while the archaeology is upstanding from the bottom and while it decays within the sediment. By adopting rapid remote geophysical survey techniques that yield quantitative information, not only can the archaeological potential and condition of sites over large areas of seabed be assessed, but provision can also be made for future monitoring of the sites. A further key part of site evaluation is the environmental setting, including factors such as the location and level of exposure of the seabed to both causes of sediment movement from natural and anthropogenic activity. The result of natural current activity on a site has been recorded by Caston (1979) in the form of scour marks and changes in the sediment properties or type around exposed wreck sites, and dredging could have a similar impact in certain circumstances.

A definitive archaeological site investigation agenda requires a multi-disciplinary approach that relies on the integration of geophysical (remote surveying), physical (sedimentological & engineering), biological, chemical, geographical and historical applications to fully understand factors affecting submerged archaeological material, its level of preservation and relative stability. The multi-disciplinary approach is therefore essential for the effective management of any form of submerged cultural heritage and it is proposed to measure and integrate the following physical factors in this project using the outlined investigation methods:

Geo-environmental Factor	Methodology	Ground Truth Methodology	Project Output
Bathymetry	Multibeam sonar (Reson 8125) (Dean and Frazer, 2004) Bathymetric sidescan sonar (Submetrix 2000) (Bates and James, 2002),	Site surveys with line and beacon	Comparative detailed bathymetric charts Archaeological site plans
Seabed sediment type and distribution	Single beam acoustic ground discrimination sonar AGDS (Echoplus) (Lawrence and Bates, 2002)	Grab sampling Diver sampling	Sediment type and strength (stability) charts
Environmental setting	Multibeam sonar (Dean and Frazer, 2004) Bathymetric sidescan sonar (Bates and Moore, 2001)	Diver observation Diver & ROV video	Broad-scale bathymetric charts Biological (Habitat) maps
Archaeological Material	Multibeam sonar (Reson 8125) (Dean and Frazer, 2004) Sidescan sonar (Datasonics, Edge Tech, Imaginex) (Quinn <i>et al</i> , Forthcoming) AGDS, Magnetometer (Gemetrics)	Diver observation Diver & ROV video	Artefact distribution maps
Historic data	Historical data analysis		Sediment transport models Site degradation estimates

The majority of these factors are now routinely measured for other near shore environmental surveys. However, their use on maritime archaeological sites has been limited. Thus an important element of this proposal will be the customisation of acoustic classification software based on environmental and military applications for archaeological artefact pattern recognition. This work will be accomplished in conjunction with Louis Atallah (University of Edinburgh, Informatics) as an extension to work already underway with AMS (BAE). Both groups are at the forefront of this type of pattern recognition technology and use will be made of this experience to establish signatures and protocols for classification of archaeological signatures using neural networks based on the full coverage multibeam data, sidescan sonar data and phase-based sonar. This work will extend the use that is currently made of single beam ground discrimination sonar and in particular will use the combined knowledge of bathymetry and backscatter for object definition and classification. The advanced use of GIS will be of particular importance here as through the use of GIS functionality such as advanced scripts multiple data types can be combined and queried for further classification. The final outcome will be a set of methodologies and practical ways of using currently available geophysical methods for not only object definition but more importantly for long term management of archaeological sites.

4.1.1 Test Sites

Two test sites will be surveyed in the project. One will be on the Hastings Shingle Banks and the other will be established within the sheltered waters of Plymouth Sound .

An area on the Hastings Shingle Bank Licence Area located approximately 15km south of Hastings has been chosen for the first test site. The survey will make use of that proposed by Wessex Archaeology in their acquisition of geophysical data (primarily sidescan data in year 1) over an area centred on the NMR listed location of the wreck the *Thomas Lawrence*. Three large sonar targets will be deployed at the site prior to commencing the survey. The targets will be tethered and buoyed so that they can be removed subsequent to the survey. A range of survey line settings will be tested by Wessex Archaeology and these will be supplemented by additional high density lines at different orientations around the sonar targets.

The second site will be located on a flat, shallow, silty sand seabed in a sheltered location within Plymouth Sound which already has an artificially target, a 5m long boat, in place. Approval will be sought from the appropriate regulating bodies to leave the additional test items on the site for future testing of geophysical and other archaeological practices, otherwise all items will be recovered.

The artificial targets will be placed in a low spring tide water depth of c.3m and surveyed with a precision long base line acoustic positioning system to allow a comparative study of multibeam and industry standard LBL acoustic methods. This will be undertaken in conjunction with the research and development staff of Sonardyne Ltd who are based in Plymouth. Surveys will be undertaken from a small vessel equipped with a rented dual head Reson SeaBat 8125 and the University's own Submetrix 2000 multibeam systems. These will be augmented by a range of sidescan sonars, including various systems owned by the Universities of St Andrews and Ulster's, together with a rented Klein 3000 system. The targets will comprise a broad range of object shapes and material types that could be found on marine archaeological sites within aggregate extraction areas, including modern intrusive material, to allow for more accurate interpretation of data from aggregate extraction areas. The targets will be broadly similar to those used in the empirical sidescan experiment conducted jointly by the Universities of St Andrews and Ulster in 2002 (Quinn *et al* forthcoming) but modified in the light of that experience and comments from peers. Potential targets are listed at the end of Appendix A.

The study will involve review and collation of archaeological, geological, environmental and biological information for each proposed test site together with extensive examination of archives. The project will involve the construction of an electronic database system compatible with those currently in use within English Heritage for the management of maritime archaeological sites. Detailed, task specific methods are presented below.

4.1.2 Wreck Site - *Stirling Castle*

The *Stirling Castle* is located on the Goodwin Sands on a series of banks off the East Kent coast that dry at low water and change shape on a seasonal and apparently rotational basis (Cloet, 1954). The exposed structure currently shows no evidence of weed growth or significant colonisation by mussels or other organisms, although reports for the Department of Culture Media and Sport by the Archaeological Diving Unit (ADU) at the University of St Andrews record such coverage in the past. This indicates that the wreck has been through a cycle of exposure, reburial and exposure which may have been triggered by sand aggregate removal for infill during the recent redevelopment of Dover Harbour.

The site has been surveyed on a number of occasions in the past and information includes archaeological and geophysical assessments undertaken by the ADU between 1986 and 2002 and by Wessex Archaeology in 2003, environmental information from the British Geological Survey and biological information from English Nature. The site will be re-surveyed using ultra high resolution and phase multibeam instruments, high definition sidescan sonar and acoustic ground discrimination systems over two field seasons. On both field surveys ground truth information will be provided by video images supported by laboratory analysis of material recovered by diver and grab samples for grain size and magnetic signature. Discussion is on-going with Wessex Archaeology and, as this site is designated under the 1973 Protection of Wrecks Act, it is proposed that joint survey time will be arranged with them. Furthermore, it is proposed that the *Stirling Castle* site is also suitable for the ALSF project on exclusion zones led by the University of Southampton.

4.2 Enhanced Geophysical Tool Evaluation

Pattern recognition techniques that have been applied for the automatic classification of sonar data (sidescan sonar, bathymetric sidescan and multibeam sonar) include those produced by Questar Tangent, Applied Acoustics and Quintech. Following the Sidescan Sonar Experiment by the Universities of Ulster and St Andrews in Belfast Lough the data was successfully processed further by Dr Louis Atallah and colleagues at the Informatics and Artificial Intelligence groups, University of Edinburgh, using algorithms based on scale-saliency methods (Timor and Brady, 2001). These algorithms will be tested on data acquired during this project from both multibeam and sidescan sonar systems. A further development in automated classification of seabed and object discrimination can be made by combining bathymetric and sidescan data. This procedure will be tested on the data for increased likelihood of classification of artefacts.

4.3 Public dissemination/outreach

4.3.1 Results of the project will be disseminated in a variety of ways. Upon acceptance of the project by English Heritage the full text of the Project Design will be placed on a project Web site. This will be maintained and updated through the duration of the project. At key stages, and upon project completion, a detailed report of the project will be produced in paper and electronic copy and submitted to English Heritage and the relevant County Archaeological (Curator) bodies. These will be supported by electronic

archives including a copy of the database and ARC GIS shape files. A version of the report will be placed on the Web. Publication of the key results in relevant journals will be undertaken including archaeologically orientated articles for the *Journal of Archaeological Science* and the *International Journal of Nautical archaeology*. A programme of public lectures will be initiated with suitable hosts to be identified in conjunction with other ALSF projects.

4.3.2 The University's Publicity Officer will issue press releases (in conjunction with EH) at appropriate points during the research and at the outset will contact TV production companies to give them the opportunity to film marine science research in action.

4.4 Specific Task Methodologies mapped to Objectives and Deliverables

M1 Background

Task M1-1 – Project Background (Objectives 1 and 2)

Objective: Refinement of knowledge and understanding of applicable techniques for mapping the environmental context of a wreck site and determining the key environmental features and stability of sites.

Method: A review of environmental factors surrounding investigation sites and previous remote sensing data acquired over the sites will be made. A synthesis of environmental conditions will lead to determination of key environmental features and an estimation of environmental stability around the project survey sites for later testing in the proposed monitoring surveys. Research into appropriate location for test site, design of test site survey plan and GIS implementation.

Deliverables: Report on methodology including recommendation on strategy for environmental monitoring of wreck sites based on current practice in archaeology and other marine monitoring disciplines. Baseline report of conditions on wreck site prior to commencing new survey monitoring. Operations plan for test site. GIS Project for integration of multiple data types.

Task M 1-2 – Project Planning and Review Meetings (Objective 10)

Objective: To keep EH informed on project progress and ensure that full integration of project is made between the project, EH and other ALSF partners.

Method: Project review meetings will be held at regular intervals throughout the project as directed by the English Heritage Project Officer. It is proposed that the meetings be attended by representatives of other ALSF projects and industry representatives. Public meetings will also be held in conjunction with EH, Wessex Archaeology and University of Southampton for the further dissemination of results.

Deliverable: Two project review meetings per year with presentations on state of the project and summary reports on achievements over last project period.

Task M1-3 – Web Site Creation (Objective 12)

Objective: Timely dissemination of information and results from the project

Method: A project web site will be constructed where the project design will be placed together with further descriptions of the sites and previous site investigations. As the project develops results will be posted with sample data available for other research groups to test algorithms. A discussion board will be hosted for interested parties to conduct online debates of issues raised during the project.

Deliverables: Web pages with information on project

M2 Enhanced Geophysical Tool Evaluation

Task M2-1 – Historic Data Testing (Objective 4, 5)

Objective: To maximise the archaeological and environmental detail obtained by high resolution sonar

Method: Refinement of algorithms for recognition of particular object shapes based on sidescan and multibeam data already held by the University of St Andrews, EH and other maritime research groups such as Wessex Archaeology. Testing of range, angle, offset, scale, resolution of different sidescan types and different objects; testing of different objects within different sea floor types. The algorithms will be tested on proprietary format data to the equipment manufacturers and also on geotiff images which are more commonly archived by survey companies.

Deliverables: Recommendations on most appropriate algorithms for testing on new monitoring data at archaeological sites.

Task M2-2 – Test of methodology on Test Site 1 (Objectives 1, 4, 5)

Note: This site will be surveyed by Wessex Archaeology as part of their ALSF project Wrecks on the Seabed R2.

Objective: Testing of discrimination algorithms on submerged material of similar nature to archaeological finds.

Method: A number of discrete targets will be placed on the seafloor prior to the survey by Wessex Archaeology. The targets will be tethered and buoyed, their position surveyed prior to the acquisition of the geophysical survey. Appropriate permission will be requested for the deployment of these temporary targets for the duration of the survey after which time they will be removed. Wessex Archaeology proposes to acquire high resolution acoustic geophysical data over the test site using a Klein 3000 sidescan sonar. This data will be acquired using varied acquisition parameters. Subsequent to acquisition the data around the target site will be processed using the new algorithms.

Deliverables: Evaluation of new target recognition algorithms on aggregate site. Comparison of geophysical acquisition parameters for specific target recognition.

Task M2-3 – Sonar Survey Software Integration (Objectives 1, 4, 5)

Objective: Integration of the sonar survey programs for generic archaeological site survey

Method: The lessons learned from all aspects of the project will be adopted within the sonar survey tests to produce a final evaluation of the effectiveness of the automated sonar classification process.

Deliverables: Evaluation of the sonar programs for generic data processing

M3 Artificial Test Site

Task M3-1 – Preparation of the Artificial Test Site (Objectives 1, 4)

Objective: Refinement of techniques for mapping environmental context of a wreck site and maximising the detail obtained from high resolution sonar on sites.

Method: After approvals have been given by appropriate authorities (Task M1-1) artificial targets will be placed at low spring tide in c.3m of water and surveyed with a Sonardyne long base line acoustic positioning system.

The geophysical surveys will then be undertaken from a small survey vessel using multibeam, bathymetric sidescan and three sidescan sonar systems. The targets will comprise a broad range of object shapes and material types that could be found on marine archaeological sites, including modern intrusive material. The targets will be broadly similar to those used in the empirical side scan experiment conducted jointly by the Universities of Ulster and St Andrews in 2002 (Quinn *et al* forthcoming) but modified in the light of that experience and comments from other researchers. A proposed list of targets is included in Appendix A and the services of a commercial registered dive team from Falmouth Divers will be used to deploy and remove the test objects.

The main part of the test site will consist of two parallel lines 50m long, 10m apart and running east to west. At intervals along the northern of the two lines one metre squares either side of the line will be covered with coarse sediments of different particle size at different stations, ranging from fine gravel to small boulders. Other pairs of one-metre squares will include a range of hard and soft biological material including skeletal material, mussel, razor clam and cockle shells, biological mats with common seaweed, and other natural material that is likely to be encountered in aggregate dredging areas.

At fixed intervals along the southern line, each pair of metre squares will contain man-made material with the largest objects on the south side of the line and the smallest to the north. The material will include small admiralty pattern anchors; broken and complete ceramics and; items made from a range of metal alloys of different size and shape. In addition man-made objects constructed from a variety of organic materials, such as leather, wood and plant material, will be included.

In nearby deeper water (>10m) a selection of targets will be laid temporarily on the seabed to allow multibeam resolution comparisons of different ranges at the same high grazing angles obtained at the closest shallow water ranges. These objects will be attached at regular intervals along a weighted and buoyed line so that deployment and recovery can be undertaken from a boat on the surface. A comparison will also be made with data collected on larger artificial targets placed in even deeper water within Plymouth Sound by the Maritime and Coast Guard Agency (MCA) as part of a sonar surveying experiment they recently undertook.

Deliverable: An artificial shallow water calibration site for testing different acoustic sonar techniques, if permission is given to leave targets *in situ*.

Task M3-2 – Testing of different sonar types, settings etc on the site (Objective 4)

Objective: Maximise the archaeological detail obtained by high resolution sonar and magnetometry.

Method: Surveys using ultra high resolution multibeam, bathymetric sidescan, three sidescan sonar systems and marine magnetometer will be undertaken over the test site. The shallow water multibeam sonar surveys will be undertaken at various states of the tide to allow high grazing angle surveys at ranges between 3m and 6m. At other states of the tide surveys with lower grazing angles (to the limit of each instrument's spread) will be undertaken giving a maximum slant range of <20m. The sidescan surveys will be undertaken at pre-determined grazing angles and offset distances to replicate the previous work by the Universities of Ulster and St Andrews. This will be an important opportunity to test the consistency of these earlier findings and to compare them with results from a Klein 3000 system, a later generation of towed sidescan sonar.

Deliverables: Report on effective use of geophysical techniques to identify and map archaeological objects and features on the seafloor within aggregate extraction areas.

B4 Stirling Castle Subtask

Task M4-1 – Review of Historic Data (Objective 6)

Objective: A better understanding of the changes in environmental factors over time that can impact a key maritime archaeological site.

Method: A comprehensive review of the historic data for the *Stirling Castle* site and immediate vicinity will be conducted prior to the field work. This will include a review of the archive data and re-processing of the geophysical data base using standard methods and also with the new pattern recognition techniques. Data acquired previously with acoustic ground discrimination sonar will be re-processed to ensure that a normalisation can be accomplished for comparison with new site data.

Deliverables: Report on present conditions on and surrounding the *Stirling Castle* site to include review of previously acquired data with new processing techniques. Enhanced baseline geophysical survey data for comparison with traditional geophysical data and ground truth data from dive and video inspection.

Task M4-2 – Stirling Castle Site Survey Year 1 (Objective 6)

Objective: Map in greater detail than previously possible the distribution of environmental factors surrounding a submerged archaeological site with one of the longest histories of regular geophysical surveys.

Method: The site will be surveyed using multibeam bathymetry, sidescan sonar, AGDS and magnetometer. Ground truth information will be provided by video inspection using divers or the University of St Andrew's VideoRay remotely operated vehicle (ROV), supported by grab samples of environmental material for later processing in the laboratory for grain size and

magnetic signature. The ground truth samples will be collected on a regular grid across the site and over the surrounding environment. Grain size and magnetic analysis will be performed at the Facility for Earth & Environmental Analysis, University of St Andrews using a Coulter LS230 laser particle size analyser and a Bartington MS2 magnetic susceptibility meter together with Molspin 'spinner' magnetometer. Discussion is on-going with Wessex Archaeology and as this site is designated under the Protection of Wrecks Act 1973, it is proposed that joint survey time is arranged with them.
Deliverable: Geophysical survey of the site including multibeam bathymetry, sidescan sonar, AGDS and bathymetry. Calibration of the site by environmental sampling including sediment and visual inspection. Report on results and tests with new processing algorithms.

Task M4-3 – Stirling Castle Site Data Reduction (Objective 7)

Objective: Assess the amount of change in environmental conditions across the *Stirling Castle* site

Method: Processing of data from *Stirling Castle* site will include standard geophysical data processing for bathymetry from the multibeam, for sidescan, for AGDS and for magnetometry. The data will be reduced to standard formats (digital bathymetric model, geotiff, magnetic gradient maps) for uploading to ArcGIS. The new algorithms will be applied to the acoustic data and these new quantitative maps will be uploaded to the GIS. Statistical comparisons will be made in GIS and the data combined with new scripts to give summary archaeological condition maps and environmental status maps after comparison with ground truth data. The ground truth data (grab sample) will be processed for sediment grain size information, magnetic signature, biological content and compared to video inspection footage. Using the GIS comparisons with previous (historic) data will be made.

Deliverable: Quantitative comparison of changes on the *Stirling Castle* site over the previous c.20 years, reporting of results.

Task M4-4 – Stirling Castle Site Survey Year 2 (Objective 7)

Objective: To assess the previous and current change in environmental conditions surrounding key sites.

Method: Geophysical survey of the site including multibeam bathymetry, sidescan sonar, AGDS and magnetometry. Calibration of the site by environmental sampling including sediment and visual inspection. Processing of the data as per Year 1.

Deliverable: Quantitative comparison of change on the *Stirling Castle* site over one year, reporting of results with particular observations on changes to site and recommendations on future monitoring activity based on noted changes.

Task M4-5 – Stirling Castle Site Data Reduction (Objective 8)

Objective: Provide information for modelling future change and long term management of site.

Method: Processing of data from *Stirling Castle* site, comparison with previous data on the site. With two years of quantitative information available a full comparison of change will be made on the site for forward scenario creation for future site changes. Data will be provided to the ALSF project on exclusion zones led by Dr Dix at the University of Southampton.

Deliverable: Full GIS compilation of results including new script method of data analysis. Report on results from new survey plus comparison with historic data.

B5 Dissemination of Results

Task M5-1 – Dissemination of results to EH and ALSF Partners

(Objectives 9, 10, 11)

Objective: Reporting and dissemination of results to EH

Method: Data analysis and reporting of the results to include recommendation on findings for use within EH future projects, use by survey companies commissioned by EH and in particular for use by aggregate companies for rapid assessment of potential submerged archaeological sites. Two scheduled meetings, including workshops, with EH and ALSF partners will be held per year throughout the project. At these meetings, it is proposed that other current ALSF contracted research projects meet to discuss and share results. A further schedule of regular meetings with the EH Project Officer (Helen On termination of the project a final review of results will be made to ensure that they are implemented within future survey programmes.

Deliverables: Presentation on results for previous session, interim reports on progress and findings with outline of work for next session including recommendations on project to date. Final reporting.

Task M5-2 – Public Dissemination (Objective 12)

Objective: Dissemination of results to a wide public audience

Method: Media will be informed of progress on the research and specific site investigations throughout this project. Public Lectures for local education and outreach within communities near to the proposed test site and survey areas is proposed. Project information will also be posted on a dedicated web site to be maintained throughout the project. The site will also host a discussion site where specific questions on the site will be answered by relevant project members. Close liaison with EH to ensure that national outreach programmes are supplied with information in timely manner.

Deliverables: Web site, public lectures, press releases.

Task M5-3 – Academic Dissemination (Objective 13)

Objective: Dissemination of results to academia

Method: It is proposed to make presentations on the research aspects of the project at forthcoming International Conferences with maritime interests, for example the Conference on Underwater Acoustic Measurements:

Technologies and Results, to be held on Crete, Greece, 2005. Publication of the academic results will be made in academic Journals such as the Journal of Archaeological Science, the International Journal of Nautical Archaeology and the International Journal of Remote Sensing.

Deliverables: Publication of conference proceedings and peer reviewed journal articles.

5 RESOURCES AND PROGRAMMING

5.1 Project team and Collaboration

5.1.1 The University of St. Andrews has significant experience in the use of advanced acoustic methods for remote, rapid marine surveys for habitat assessment, engineering evaluation and geological mapping. For example, recent contracts include evaluation of Special Areas of Conservation for English Nature and Scottish Natural Heritage in addition to archaeological appraisal and investigation for English Heritage and Historic Scotland. Valuable experience has also been gained at St Andrews in conjunction with the Centre for Maritime Archaeology at the University of Ulster in the ensonification of archaeological material exposed on the seabed. Marin Dean (University of St Andrews) will be assisted by Mr Philip Robertson as part time project officer for the archaeological assessment of results within the project. Biological assessment will be conducted by Mr Fernando Tempera (University of St. Andrews). Mr Tempera has considerable experience in a range of biological assessment programmes for long term monitoring conditions of change. Louis Atallah at the Informatics and Visualisation Group, University of Edinburgh and Dr Iain Goodfellow, AMS Dorchester have considerable experience in developing software for automated acoustic character recognition for military and environmental applications. Their expertise will be used for the software development with the Edinburgh group specifically commissioned to work on the project. AMS will provide review experience through access to their own inhouse, proprietary software. Topaz Environment and Marine (TEAM) is a consulting company with extensive experience in the application of GIS based solutions to marine mapping. They will be commissioned to adapt the results of the analysis by the University of Edinburgh to standard GIS products using the ESRI ArcGIS suite of programmes. Summary CVs are given for key personnel in Appendix B

5.2 Collaboration

Understanding the transition zone will require specific information and results Following work on the *Stirling Castle*, key environmental data on bed altitude, sediment distribution and artefact exposure will be passed on to Dr Justin Dix, University of Southampton for modelling under the ALSD project Modelling Exclusion Zones for Maritime Aggregate Dredging. A critical element to the evaluation of rapid assessment techniques is high quality ground truth data. Ground truth information, data from previous surveys and current on-going monitoring will be obtained through close collaboration with Wessex Archaeology. During and subsequent to testing of the geophysical methods, close collaboration will be maintained with Wessex Archaeology in order that recommendations on surveying can be adopted within the Wrecks on the Seabed programme. In addition, the following people have interests or responsibilities for the Stirling Castle with whom the research program has been discussed. The County Archaeologist for Kent is John Williams - 01622 221534 john.williams@kent.gov.uk and Norman Temple, the Chairman of East Kent Maritime Trust has curatorial responsibility for the Stirling Castle. The owner of the Stirling Castle was the Isle of Thanet Archaeological Unit – now the Trust for Thanet Archaeology -contact name, Dave Perkins 01603

54432. The current Licensee under the Protection of Wrecks Act 1973 is Bob Peacock - 01304 360965. Under the project plan each of these people will be kept fully informed of all results and progress on the project.

5.3 Project management

5.3.1 The project will be managed by Dr. Richard Bates of the University of St Andrews with close academic support provided by Mr Martin Dean, University of St Andrews. Martin Dean will also provide key archaeological experience in all aspects of the project. The project will be supported by Mr Philip Robertson as a part time archaeology project officer who will have responsibility for the review of archaeological data, for integration with the geophysical data and for support during field sonar acquisition. Biological analysis will be provided for the field work by Fernando Tempera, University of St Andrews. Support for management will be provided by administrative and support staff at the University of St Andrews.

5.3.2 Project Advisory Group

A project advisory group will be setup at the beginning of the project to review progress and ensure that deliverables are being met and are of a format that is best useable by EH. The group will consist of members of this project (Dr Richard Bates and Martin Dean) and members of the Wessex Archaeology (Dr Anthony Firth) and the University of Southampton (Dr Justin Dix).

5.4 Task list

5.4.1 Five major task-groupings (Elements) were identified within the project and have been listed in greater detail in section 4.4. The tasks are further detailed in the full schedule, Appendix D :

5.4.2 Time for project management will also need to be allocated throughout the project for both management and liaison between project members and with members of other complementary ALSF funded projects. Detailed breakdowns of the specific tasks required for each of the project elements are presented in Appendix D.

5.5 Equipment

5.5.1 Key elements of equipment required for the successful implementation of this project centre on the advanced computing and software elements of the project. In particular for support of the multibeam surveys it is proposed to use Fledermaus (IVS) and to test QTC Multiview and Clams for visualisation of the seafloor images and classification of the seafloor texture. Proprietary software developed for classification and quantification of acoustic data will be available throughout the programme from the Universities of St Andrews and Edinburgh. No equipment hardware will be acquired within the project, rather the necessary survey equipment not already owned by the University of St Andrews will be rented, including Reson and Klein sonar systems together with local survey vessels where necessary. The University of St Andrews will provide equipment hardware including the acoustic ground discrimination system (Echoplus, SEA), bathymetric sidescan (SwathPlus, Submetrix), a

marine magnetometer (Geometrics 881) an ROV (VideoRay) and, where appropriate, the Survey Launch *Envoy*.

Proprietary software under development by the University of Edinburgh and AMS will be provided for the duration of the project.

5.4.2 No other major items of equipment will be required.

5.6 Facilities and Institutional support

5.5.1 The laboratory based scientific aspects of the project will utilise the facilities at the School of Geography and Geosciences, University of St Andrews. These include specialised facilities for environmental analysis, sediment particle analysis, magnetic analysis, sample storage, preparation, and processing.

5.7 Budget

5.7.1 Details of the project budget are presented in Appendix C.

5.8 Timetable

5.8.1 The project is designed to commence on 1st November 2004. The duration of the project is scheduled for 21 months with a completion date set of 1 July 2006. A brief outline of the project schedule is given in table 1 below with a full schedule and milestones given in Appendix D.

Tasks	2004	2005				2006		
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Project Planning								
Historic data analysis (St. And)								
Acoustic Survey software adaptation and integration (AMS)								
Site Survey 1 (Artificial Test Site)								
Site Survey 2 (<i>Stirling Castle</i>)								
Site Survey 4 (<i>Stirling Castle</i>)								
Final Report								

5.9 Health and Safety

5.9.1 The project will follow the standard health and safety protocols operated by the School of Geography and Geosciences, University of St. Andrews. In particular, as for all projects, a risk assessment will be conducted at the outset of each project element, particularly those involving fieldwork, in which possible health and safety hazards are identified and appropriate risk-mitigation actions and procedures identified. All risk assessments will need to be approved by the designated Health and Safety officers in relevant departments of the University before any activity commences.

6 QA/QC

The project will follow quality assessment and quality control criteria established by the School of Geography and Geosciences for best practice in other environmental work. This will include the following sub-tasks:

6.0.1 Monitoring – the project will be monitored externally by English Heritage using a management structure defined by English Heritage but likely to contain project officers and members of the Maritime Team. The project will be directly accountable to these officers and progress will be reported at appropriate milestones using project meetings to the officers as set out by the project milestones.

6.0.2 Field Quality Standards and Quality Control will follow methodologies developed by the School of Geography and Geosciences for general best practice for environmental survey and closely follow those outlined by the UK Offshore Operators Association. These standards are supplemented by the code of practice outlined in The Code of Conduct and The Code of Approved Practice for the Regulation of Contractual Arrangements in Field Archaeology of the Institute of Field Archaeologists.

6.0.3 Project deadlines - the defined project timescale and project milestones will be used to monitor and control progress through the project. Specifically, the milestones will be used by the project manager to inform English Heritage of achievements and to highlight potential delays before they become an issue within the overall programme.

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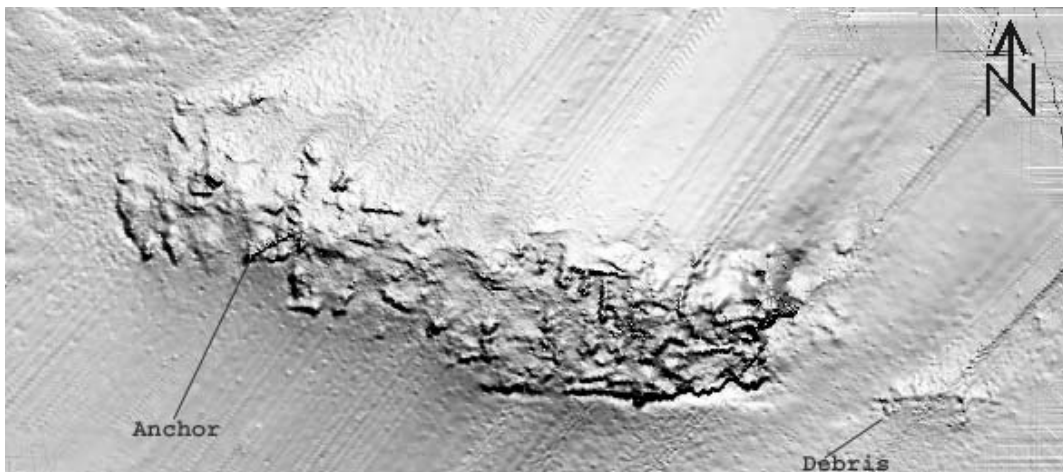
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8 FIGURES

Figure 1 – Multibeam image of SMS Markgraf, Scapa Flow, scuttled in 1919 (ScapaMap, University of Heriot Watt/ ADU, University of St Andrews/ Reson Offshore Ltd)



Figure 2 – Multibeam image of the Stirling Castle, Goodwin Sands, which sank in 1703 (ADU, University of St Andrews/ Reson Offshore Ltd)



Appendix A
Historic patterns of marine aggregate extraction (tonnes)
(Figures exclude beach replenishment and fill contracts)

Extraction Area	1991	1992	1993	1994	1995
Humber	0	0	0	1,910,064	1,788,452
<i>East Coast</i>	9,220,517	10,255,813	9,812,236	9,384,860	10,497,352
Thames	1,505,111	1,504,471	1,223,190	2,001,208	1,661,324
South Coast	5,280,685	4,794,290	4,361,796	4,932,372	4,428,357
South West Coast	2,065,841	2,388,148	2,172,576	2,259,046	2,285,899
North West Coast	305,654	310,782	380,336	290,846	278,126
Rivers & Misc.	40,236	17,998	12,651	14,491	14,114
Yearly Total	18,418,044	19,271,502	17,962,785	20,792,887	20,953,624

Extraction Area	1996	1997	1998	1999	2000	2001	Total
Humber	1,903,678	2,351,233	2,694,977	2,840,261	3,122,080	2,933,623	19,544,368
<i>East Coast</i>	9,306,920	9,397,705	8,923,562	9,131,512	9,129,635	9,636,697	104,696,809
Thames	1,115,597	1,125,921	862,834	971,960	854,483	909,141	13,735,240
South Coast	4,738,402	4,733,825	5,821,701	5,885,332	5,613,538	5,628,008	56,218,306
South West Coast	2,019,305	2,048,014	1,886,289	1,719,803	1,602,394	1,549,431	21,996,746
North West Coast	287,251	284,497	275,590	355,044	316,090	421,068	3,505,284
Rivers & Misc.	21,784	18,587	6,238	6,273	46,120	73,047	271,539
Yearly Total	19,392,937	19,959,782	20,471,191	20,910,185	20,684,340	21,151,015	219,968,292

Table 1 Suggested list of test site targets (Dimensions based on Belfast Lough experiment)

Type	Dimensions
0.2m diameter Al tube	Vertical; H = 0.64m
0.2m diameter Al tube	45° to S; H = 0.42m
0.2m diameter Al tube	45° to N; H = 0.48m
0.2m diameter Al tube	Vertical; H = 0.40m
0.2m diameter Al tube	Vertical; H = 0.20m
0.2m diameter Al tube	Vertical; H = 0.78m
0.1m diameter Al tube	45° to S; H = 0.40m
0.1m diameter Al tube	Vertical; H = 0.70m
0.1m diameter Al tube	45° to N; H = 0.45m
0.1m diameter Al tube	Vertical; H = 0.21m
0.1m diameter Al tube	Vertical; H = 0.08m
Green softwood post	0.1x0.1 m; H = 0.10m
Green softwood post	0.1x0.1 m; H = 0.425m
0.05m diameter Al tube	45° to S; H = 0.53m
0.05m diameter Al tube	Vertical; H = 0.55m
0.05m diameter Al tube	45° to N; H = 0.52m
0.05m diameter Al tube	Vertical; H = 0.80m
0.05m diameter Al tube	Vertical; H = 0.80m
0.05m diameter Al tube	Vertical; H = 0.53m
Green softwood post	0.05x0.03 m; H = 0.19m
Green softwood post	0.05x0.03 m; H = 0.42m
0.025m diameter Al tube	45° to S; H = 0.43m
0.025m diameter Al tube	Vertical; H = 0.568m
0.025m diameter Al tube	45° to N; H = 0.41m
0.025m diameter Al tube	Vertical; H = 0.40m
0.025m diameter Al tube	Vertical; H = 0.08m
0.025m diameter Al tube	Vertical; H = 0.06m
0.025m diameter Al tube	Vertical; H = 0.025m
0.025m diameter wood broom handle	Vertical; H = 0.04m
0.025m diameter wood broom handle	Vertical; H = 0.07m
0.025m diameter wood broom handle	Vertical; H = 0.12m
0.025m diameter wood broom handle	Vertical; H = 0.23m
0.025m diameter wood broom handle	Vertical; H = 0.21m
0.006m steel rod	Horizontal
0.006m steel rod	45° to S; H = 0.21m
0.006m steel rod	Vertical; H = 0.38m
0.006m steel rod	45° to N; H = 0.24m
0.65m diameter car tyre	Vertical; H = 0.60m
0.65m diameter car tyre	Horizontal; H = 0.20m
'Amphora' shoulder and neck	H = 0.35; Diameter at mouth = 0.18m
Ceramic ball	Diameter = 0.26m
Upturned hemispherical twig basket	Diameter = 0.17m
Willow 'fish basket'	H = 0.38m; L = 1.2m
Woven grass basket	0.40x0.24x0.16m
Upstanding leather jacket	H = 0.70m; L = 1.0m
Green softwood trellis	H = 0.90m; L = 1.5m
0.05m diameter aluminium radar reflector	Vertical; H = 0.90m off bed
0.10m diameter aluminium radar reflector	Vertical; H = 0.88m off bed
0.30m diameter aluminium foil covered float	Vertical; H = 0.66m off bed
0.20m diameter Al tube	Vertical; H = 0.83m

Type	Dimensions
3 x 0.20m diameter Al tubes arranged horizontally:	1.0m x 2.0m

3 x 0.10m diameter Al tubes arranged horizontally: one N-S, one E-W, one SW-NE	1.0m x 2.0m
3 x 0.05m diameter Al tubes arranged horizontally: one N-S, one E-W, one SW-NE	1.0m x 2.0m
3 x 0.025m diameter Al tubes arranged horizontally: one N-S, one E-W, one SW-NE	1.0m x 2.0m
Type	Dimensions
0.30m diameter earthenware flower pots standing end-on-end	H = 0.60m
100% coverage 0.15m diameter flower pots	H = 0.30m
50% coverage 0.15m diameter ceramic pots	H = 0.25m
100% coverage glazed pot sherds	-
50% coverage glazed pot sherds	-
4 x waterlogged oak ships timbers	1.5m; 1.5m; 1.5m; 1m
100% Flint cobbles	0.01-0.06m; 1.0m ²
50% Flint cobbles	0.01-0.06m; 1.0m ²
100% coverage glass bottles	Horizontal
50% coverage glass bottles	Horizontal
100% coverage pebbles	1.0m ²
50% coverage pebbles	1.0m ²
100% coverage 10mm aggregate	1.0m ²
50% coverage 10mm aggregate	1.0m ²
Articulated human skeletal remains	1.0m ²
30% coverage dis-articulated skeletal remains	1.0m ²
100% coverage 12.5mm iron nails	1.0m ²
50% coverage 10mm iron nails	1.0m ²
Sand mound	H = 0.10m; Diameter = 0.227m
Shallow pit	D = 0.15m; Diameter = 0.234m
E-W orientated rack of 0.05m diameter Aluminium tubes	1.0m ²
3mm Aluminium sheet	1.0m ²
8-limb star shape formed by 0.20m Aluminium tubes	1.3m ²
2 1.0x1.0m Aluminium angle frames	1.0m x 2.0m
E-W orientated rack of 0.20m and 0.10m diameter Aluminium tubes	1.0m x 1.6m
0.30m diameter ceramic flower pot	H = 0.30m

Appendix B

Summary CV for Key Staff

Dr Richard Bates, School of Geography & Geosciences, University of St Andrews, St Andrews, Fife, KY16 9AL, Phone +44 1334 463997, Email crb@st-andrews.ac.uk

Education:

1982-1986 B.Sc., Geology, Edinburgh University
1986-1989 Ph.D., Applied Geophysics, University of N. Wales, Bangor
1994 C. Geol, Geology Society of London

Career:

1989-1992 Project Geophysicist - Blackhawk Geosciences, Inc.
1992-1995 Geophysicist - Coleman Energy and Environmental Services
1995-1996 Senior Geophysicist - Thermoelectron Corporation
1996-present Lecturer, Geography & Geosciences, University of St Andrews

Research Interests:

Research interests and activities: Applied geophysics in marine and terrestrial palaeo-environmental reconstruction, multicomponent seismics, sonar development

Recent Publications:

- Bates, M.R., Bates, C.R., Gibbard, P.L., Macphail, R.I., Owen, F.J., Parfitt, S.A., Preece, R.C., Roberts, M.B., Robinson, J.E., Whittaker, J.E. and Wilkinson, K.N. 2000 Late Middle Pleistocene deposits at Norton Farm on the West Sussex Coastal Plain, Southern England. *Journal of Quaternary Science*, v. 15 (1), pp. 61-89.
- Bates, M.R. and Bates, C.R., 2000. Multi-disciplinary approaches to the geoarchaeological evaluation of deeply stratified sedimentary sequences: examples from Pleistocene and Holocene deposits in Southern England, United Kingdom. *Journal of Archaeological Science*, v. 27, no. 9, pp. 845-858.
- Bates, C. R. and Byham, P. 2001. Swath-sounding techniques for near shore surveying. *The Hydrographic Journal*, v. 100, pp. 13-18.
- Bates, C. R. and Whitehead, J. 2001. Echoplus measurements in Hopvagen Bay, Norway. *Sea Technology*, v. 42, No. 6, pp. 34-43.
- Bates, C. R. and Moore, C. 2002, Acoustical Methods for Marine Habitat Surveys. *HydroInternational*, Vol. 6, No. 1, pp. 47-49.
- Lawrence, M. L. and Bates, C. R. 2002. Acoustic Ground Discrimination Techniques for Submerged Archaeological Site Investigations. *Marine Technology Society Journal*, v. 35, No. 4, pp. 65-73.
- Bates, C. R. and James, B. 2003. Marine GIS for management of Scottish marine Special Areas of Conservation. *Marine Geography: GIS for the Oceans and Seas*, ed. Breman, J. ESRI Press.
- Atallah, L., Probert Smith, P. and Bates, C. R. 2003. Wavelet Analysis for the Classification of Hopvagen Bay, Norway using a Bathymetric Sidescan Sonar. In press, *Marine Geology*.
- Bates, C. R. and Oakley, D. Bathymetric sidescan investigation of sedimentary features in the Tay Estuary, Scotland. In Press *International Journal of Remote Sensing*.

Mr Fernando Tempera, School of Geography & Geosciences, University of St Andrews, St Andrews, Fife, KY16 9AL, Ph: +44 1334 462383, Email: fnct@st-andrews.ac.uk

Education:

- 1992-1997 "Licenciatura" degree, Marine Biology, Lisbon University
2003-ongoing Ph.D. student, School of Geography & Geosciences, Univ. of St Andrews

Career:

- 1998-2003 Project Marine Biologist - Dept. of Oceanography and Fisheries - University of the Azores (Portugal)
2003-ongoing Ph.D. student, Geography & Geosciences, University of St Andrews

Research Interests:

Research interests and activities: Marine Biotope Mapping, Management of Marine Protected Areas, Geographic Information Systems (GIS).

Recent Publications:

THESIS

Tempera, F.N.C. (1997). Study on the spatial variation of the fish assemblages of the Faial-Pico channel (Azores). *Report of the curricular project within the "Marine Biology" degree* (in Portuguese). Faculty of Sciences of the University of Lisbon. 94pp.

SCIENTIFIC PAPERS

- Ávila, S.P., J. Fontes, F. Tempera & F. Cardigos. 2000. Additions to the Marine Molluscs of the Formigas Islets, Azores. *Açoreana*, Vol. 9, No. 2:175-178.
Fontes, J., F. Tempera & P. Wirtz. 2001. On some interesting opisthobranchs from the Azores (Mollusca Gastropoda Opisthobranchia). *Arquipélago*. Life and Marine Sciences, No. 18A: 85-87.

TECHNICAL-SCIENTIFIC REPORTS

- Ferraz R. R., N. Carvalho, F. Tempera, C. Alves & Ricardo S. Santos. 2000. Characterization of the Marine Environment for the Coastal Planning of São Miguel Island – section Feteiras-Lomba de São Pedro – Final Report (in Portuguese). *Arquivos do DOP*, Série Estudos N° 3/2000, 118 pp.
Tempera, F., P. Afonso, T. Gomes & R. Santos. 2001. Biological Communities of the Formigas Islets and Dollabarat Reef SAC (in Portuguese). Departamento de Oceanografia e Pescas da Universidade dos Açores, Horta. *Arquivos do DOP*. Série Relatórios Internos, n° 3/2001, iii+43 pp.
Tempera, F., P. Afonso, T. Morato, S. Gubbay, T. Dentinho, F. Cardigos, M.J. Pitta & R. Serrão Santos. 2001. Technical-Scientific Planning Proposal for the Formigas Islets and Dollabarat Reef SAC (in Portuguese). Departamento de Oceanografia e Pescas da Universidade dos Açores, Horta. *Arquivos do DOP*. Série Relatórios Internos, n° 4/2001, v+17 pp.
Tempera, F., P. Afonso, T. Morato, R. Prieto, M. Silva, A. Cruz, J. Gonçalves & R. Serrão Santos. 2001. Biological Communities of the Faial-Pico Channel SACs (in Portuguese). Departamento de Oceanografia e Pescas da Universidade dos Açores, Horta. *Arquivos do DOP*. Série Relatórios Internos, n° 7/2001, vi+95 pp.
Tempera, F., P. Afonso, T. Morato, S. Gubbay, T. Dentinho, M. Silva, R. Prieto, F. Cardigos, M.J. Pitta & R. Serrão Santos. 2001. Technical-Scientific Management Proposal for the Faial-Pico Channel SACs (in Portuguese). Departamento de Oceanografia e Pescas da Universidade dos Açores, Horta. *Arquivos do DOP*. Série Relatórios Internos, n° 8/2001, viii+76 pp.
Tempera, F., P. Afonso, T. Morato & R. Serrão Santos. 2002. Marine Biological Communities of Corvo Island (in Portuguese). Departamento de Oceanografia e Pescas da Universidade dos Açores, Horta. *Arquivos do DOP*. Série Relatórios Internos, n° 1/2002, iv+52 pp.
Tempera, F., F. Cardigos, P. Afonso, T. Morato, M. J. Pitta, S. Gubbay & R. Serrão Santos. 2002. Technical-Scientific Management Proposal for the Marine Environment of Corvo Island (in Portuguese). Departamento de Oceanografia e Pescas da Universidade dos Açores, Horta. *Arquivos do DOP*. Série Relatórios Internos, n° 2/2001, vi+57 pp.

Martin Dean, School of History, University of St Andrews, St Andrews, Fife KY16 9AJ, Phone 01334 462900, Email mld@st-andrews.ac.uk

Education:

1973 – 1977 B.Sc., Archaeology, Institute of Archaeology, University of London

Career:

1981 – 1986 Diving Archaeologist, National Maritime Museum, Greenwich

1986 – 2002 Director, Archaeological Diving Unit, University of St Andrews

2003-ongoing Senior Research Fellow, University of St Andrews

Research Interests:

The exploitation and development of ultra high resolution sonar for archaeological surveying and site assessment. The application of solutions developed in other industries to the problems encountered in archaeology underwater. The construction and use of watercraft pre 1500ad. The development of submarines pre 1914.

Recent Publications:

- Dean M., Ferrari B., Oxley I., Redknap M. and Watson K. (eds.) 1995.
Archaeology Underwater: The NAS Guide to Principles and Practice. Archetype Press, London.
- Clarke, Dean, Hutchinson, McGrail and Squirrell, 1993.
Recent work on the R. Hamble near Bursledon, Hampshire, in *International Journal for Nautical Archaeology* 22.1:21-44
- HSE, 1997. (Dean, M., Lonsdale, P. and Sayer, M.)
Approved Code of Practice for Scientific and Archaeological Diving, London
- Dean M. 1998.
The submarine boat *Resurgam*, in *Maritime Heritage* 2.2
- Dean M. 1999.
A review of marine archaeology, in *Irish Sea Forum* 21. Liverpool.
- Quinn R. and Dean M. 2000.
Comparison of the Maritime Sites and Monuments Record with Side-Scan Sonar and Diver Surveys, in *Geoarchaeology* 17:5
- Dean M., Lawrence M., Liscoe S. and Wood A. 2000.
Protected Historic Wrecks: Guidance: Notes for divers and archaeologists. St Andrews.
- Quinn R. and Dean M., 2002.
Side-scan sonar and maritime archaeology - a control experiment, in *Archaeology Ireland* 16:1
- Dean M. & Frazer J., 2004.
The Application of High Resolution Multibeam Sonar to the Investigation of Archaeological Sites Underwater. *The Application of Recent Advances in Underwater Detection and Survey Techniques to Underwater Archaeology* (ed. Tuncay A., Ballard R., and Bass G.). Bodrum
- Quinn R., Dean M. and Bolan D., Forthcoming.
Backscatter responses and resolution considerations in archaeological side-scan sonar surveys: a control experiment, in *Journal of Archaeological Science*

Mr Phil Robertson, School of Geography & Geosciences, University of St Andrews, St Andrews, Fife, KY16 9AL

Education:

1988-1991 B.A. Hons Classics, Bristol University

1991-1994 M.Litt. Maritime Studies, St Andrews University

Career:

1992-1993 Maritime SMR Officer - East Sussex County Council

1993-1996 Marine Warden, East Sussex County Council

1996-present Sole Trader and Freelance Archaeologist T/A: Lochaline Dive Centre

Professional experience as a freelance archaeologist

2004 Specialist consultant (marine archaeology) for the South Downs National Park Public Enquiry – Contracted by the South Downs campaign group

2004 Sound of Mull remote sensing project – Instigator, project manager and archaeologist on a major multibeam/ sidescan recording project in conjunction with Dundee University, Historic Scotland, Kongsberg Simrad and Aspect Surveys.

2003-4 A consultant for Wessex Archaeology's Archaeological services contract in support of the Protection of Wrecks Act, 1973.

2002 Archaeological advisor for the Burntisland historic shipwreck project

2001-3 Director of the Kinlochbervie shipwreck investigation. Obtained funding from Historic Scotland and managed the project through to publication.

1999-2000 Team member on the investigation of the *Swan* shipwreck (1999-2000)

1997- NAS Training Officer for Scotland – contracted to NAS and Historic Scotland to provide training, outreach and promotional activities in maritime archaeology in Scotland.

1996-7 Coastal survey of Fife for Maritime Fife, St Andrews University.

1995- Visitor Scheme licensee on HMS Dartmouth and Swan.

1995-6 Archaeological assessment of Lundy Marine Nature Reserve.

1995-6 Diving archaeologist on contracts at Folkestone and Plymouth for Wessex Archaeology.

1994- Instigator of the Sound of Mull Archaeological Project (SOMAP), coordinating NAS trainees on research projects in the Sound of Mull.

Recent Publications:

Robertson, P., 2004, A shipwreck near Kinlochbervie, Sutherland, Scotland, UK. *International Journal of Nautical Archaeology*. 33.1:14-28. Awarded *Highly Commended* in the Keith Muckelroy Memorial Award category of the British Archaeological Awards 2004.

Robertson, P., 2003, 'The Visitor Schemes on the Historic Shipwrecks of the *Swan*, and *HMS Dartmouth*, Sound of Mull, Scotland (UK)' in J Spirek, & D A. Scott-Ireton (eds) *Submerged Cultural Resource Management: preserving and interpreting our sunken maritime heritage*. Plenum Series in Underwater Archaeology. New York, pp.71-83

Robertson, P., 2003 'Assessment survey: Fife' in Dawson, T., and Ashmore, P., (eds) *Coastal Archaeology and Erosion in Scotland - Conference Proceedings*. pp.107-126 Historic Scotland

Robertson, P., and Heath, J., 1997 Marine Archaeology and Lundy. In R. Irving, J. Schofield, and C. Webster (eds) *Island studies, Fifty Years of the Lundy Field Society* pp.77-86. Devon, UK

Dr Louis Atallah, The British University in Dubai/ University of Edinburgh,
Knowledge Village, P.O. Box: 502216 Dubai, UAE. Tel: +971 4 3913626, Fax: +971
4 366 4698. Email: louis.atallah@buid.ac.ae and latallah@inf.ed.ac.uk

Education:

- 1995-2000 M. Eng in Electrical and Electronics Engineering- The Lebanese
University- Beirut- Lebanon
- 2000-2004 Ph.D., Engineering Science, University of Oxford

Career:

- 1999-2000 Software Development Engineer, Mideast Data Systems.
- 2002-2003 Lecturer in Lincoln College, University of Oxford
- 9/2003-present Visiting Lecturer at the University of Edinburgh
- 9/2003-present Lecturer in Informatics and admissions tutor at the British University in
Dubai.

Research Interests:

Research interests and activities: Machine learning for computer
vision, sonar seabed classification and object detection, texture
analysis in images and modelling Arabic handwriting.

Recent Publications:

- L. Atallah and PJ. Smith. 2002. Using Wavelet analysis to classify and segment
sonar signals scattered from underwater sea beds., Acta Acustica united with
Acustica, volume 88, number 5, pages: 615-618
- L Atallah and PJ Smith. 2002. Using Wavelet analysis to classify and segment
sonar signals scattered from underwater sea beds. Proceedings of the sixth
European Conference on Underwater Acoustics, ECUA'2002, 24-27 June
2002, Gdansk, Poland, Editor: A. Stepnowski, co-editors: R. Salomon and A.
Partyka pages: 59-64.
- L. Atallah, PJ. Smith and C. R. Bates. 2002. Wavelet analysis of bathymetric
sidescan sonar data for the classification of seafloor sediments in Hopvagen
Bay - Norway., Marine Geophysical Researches Vol. 23 (5-6), pages 431-
442
- L. Atallah and PJ. Smith. 2003. Using wavelet analysis to classify and segment
sonar signals scattered from underwater seabeds. . International Journal of
Remote Sensing. Vol 24 (21), pages 4113-4128.
- L. Atallah and PJ Smith. 2004. Automatic Seabed Classification by the Analysis
of Sidescan Sonar and Bathymetric Imagery. Accepted for Publication, IEE
Radar, Sonar and Navigation.
- L. Atallah. 2004. Can bathymetric data be used to classify underwater seabeds?
Accepted for the 148th meeting of the Acoustical Society of America, San
Diego

Appendix C Cost Summary

Project

Year

Y1 -
2004

Unit Staff	Per	Cost	Units	Cost
Project Manager (Richard Bates)	day	£250.00	25	£6,250.00
Project Officer (Philip Robertson)	day	£150.00	35	£5,250.00
Marin Dean	day	£250.00	8	£2,000.00
Total Salary Cost			Sub Total A	£13,500.00
External Fees				
Software Adaptation (L Atallah, Edinburgh)	day	£250.00	25	£6,250.00
Geophysical Survey - Test Site 1	day	£2,345.00	2	£4,690.00
GIS Software Adaption (TEAM)	day	£150.00	15	£2,250.00
Total Fees			Sub Total B	£13,190.00
Non Staff Costs				
Transport	day	£39.00	6	£234.00
Accommodation	day	£45.00	6	£270.00
Miscellaneous	day	£80.00	5	£400.00
Meetings at Fort Cumberland - transport	day	£75.00	6	£450.00
Total non-staff costs			Sub Total C	£1,354.00
Overheads				
Unit overheads (sub-total A+C) @25%			£3,713.50	£18,567.50
Overhead on external fee (sub-total B)@10%			£1,319.00	£14,509.00
			£5,032.50	
Gross total				£33,076.50

Project				
Year		Y2 - 2005		
Unit Staff	Per	Cost	Units	Cost
Project Manager (Richard Bates)	day	£250.00	40	£10,000
Project Officer (Philip Roberston)	day	£150.00	85	£12,750
Marin Dean	day	£250.00	27	£6,750.00
Biological Analysis (Fernando Tempera)	day	£150.00	2	£300.00
Total Salary Cost			Sub Total A	£29,800
External Fees				
Geophysical Survey - Artificial Test Site	day	£4,345.00	5	£21,725.00
Geophysical Survey - Stirling Castle	day	£4,345.00	5	£21,725.00
Software Adaptation (L Atallah, Edinburgh)	day	£250.00	20	£5,000.00
GIS Software Adaption (TEAM)	day	£150.00	15	£2,250.00
Falmouth Divers	day	£2,175.00	4	£8,700.00
Total Fees			Sub Total B	£59,400.00
Non Staff Costs				
Transport	day	£39.00	20	£780.00
Accommodation	day	£45.00	30	£1,350.00
Miscellaneous	day	£80.00	15	£1,200.00
Meetings at Fort Cumberland - transport	day	£75.00	6	£450.00
Total non-staff costs			Sub Total C	£3,780.00
Overheads				
Unit overheads (sub-total A+C) @25%			£8,395.00	£41,975.00
Overhead on external fee (sub-total B)@10%			£5,940.00	£65,340.00
			£14,335.00	
Capital Equipment				
Total Capital Equipment				
Gross total				£107,315.00

Project				
Year		Y3 - 2006		
Unit Staff	Per	Cost	Units	Cost
Project Manager (Richard Bates)	day	£250.00	35	£8,750
Project Officer (Philip Roberson)	day	£150.00	63	£9,450
Marin Dean	day	£250.00	17	£4,250.00
Biological Analysis (Fernando Tempera)	day	£150.00	2	£300.00
			Sub Total	
Total Salary Cost			A	£22,750
External Fees				
Geophysical Survey - Stirling Castle	day	£4,345.00	5	£21,725.00
Software Adaptation (L Atallah, Edinburgh)	hr	£250.00	20	£5,000.00
			Sub Total	
Total Fees			B	£26,725.00
Non Staff Costs				
Transport	day	£39.00	20	£780.00
Accommodation	day	£45.00	30	£1,350.00
Miscellaneous	day	£80.00	15	£1,200.00
Meetings at Fort Cumberland - transport		£75.00	6	£450.00
			Sub Total	
Total non-staff costs			C	£3,780.00
Overheads				
Unit overheads (sub-total A+C) @25%			£6,632.50	£33,162.50
Overhead on external fee (sub-total B)@ 10%			£2,672.50	£29,397.50
			£9,305.00	
Capital Equipment				
Total Capital Equipment				
Gross total				£62,560.00

