Report No: 2009R091

Royal Anne Galley
Lizard Point, Cornwall

Marine Environmental Assessment
Phase 2 Field Assessment Report

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CORNWALL COUNCIL

Historic Environment Projects

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Client	**English Heritage**
Report Number	**2009R091**
Date	**04 December 2009**
Status	**Final**
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Acknowledgements

This study was commissioned by English Heritage and carried out by the projects team of Historic Environment, Environment. Planning and Economy, Cornwall Council with a team of marine consultants and contractors. Within the Historic Environment, the Project Manager was Charles Johns.

Diving and bathymetric survey were carried out by SeaStar Survey Ltd of Southampton with advice from local diver Mike Hall and under the direction of Kevin Camidge; the biological survey was carried out by Miles Hoskin of Coastal and Marine Environmental Research, Falmouth (CMER), the samples were analysed by Derwentside Environmental Services, Ian Panter, Principal Conservator, York Archaeological Trust carried out a geochemical assessment of the sediment and seawater seabed samples and Matt Canti, Geoarchaeologist, English Heritage analysed the sediment sample.

This report is dedicated to the late Robert Sherratt who rediscovered the wreck of the *Royal Anne* Galley in 1991 and was formerly the licensee of the site.

The views and recommendations expressed in this report are those of the Historic Environment projects team and are presented in good faith on the basis of professional judgement and on information currently available.

Freedom of Information Act

As Cornwall Council is a public authority it is subject to the terms of the Freedom of Information Act 2000, which came into effect from 1st January 2005.

Historic Environment, Cornwall Council is a Registered Organisation with the Institute for Archaeologists

Cover illustration

Diver with sediment sample tubs (photo SeaStar Ltd)

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Abbreviations

CMER	Coastal and Marine Environmental Research
DBA	Desk Based Assessment
EH	English Heritage
FEPA	Food and Environment Act
GPS	Global Positioning System
HER	Cornwall and the Isles of Scilly Historic Environment Record
HE	Historic Environment, Cornwall Council
JNCC	Joint Nature Conservancy Council
MEA	Marine Environmental Assessment
NGR	National Grid Reference
OS	Ordnance Survey
SAC	Special Area of Conservation
SRB	Sulphate Reducing Bacteria

1 Summary

This report describes the results of the Phase 2 field assessment of the *Royal Anne* Galley, a protected wreck site lying of the Lizard Point, carried out for English Heritage by Historic Environment Projects, Cornwall Council with a team of marine consultants and contractors in 2008 and 2009 as part of the marine environmental assessment of the site.

The *Royal Anne* Galley was a galley frigate, a type of small, fast warship, combining sail with oar propulsion. Built at Woolwich Dockyard in 1709, she was wrecked off the Lizard on 10th November 1721. About two hundred crew and passengers were lost including John, 3rd Lord Belhaven, who was en voyage to take up a new post as the Governor of Barbados.

The wreck site was rediscovered in 1991 by local diver Robert Sherratt when a large sounding lead was found adjacent to two iron guns. Subsequently numerous objects were recovered from the seabed in the vicinity of the iron guns, including items of cutlery bearing the Belhaven crest, which led to the identification of the wreck. The wreck was designated under the Protection of Wrecks Act (1973) as the *Royal Anne* Galley in 1993. The designation extends for a radius of 200m from position Latitude 49° 57'.48N, Longitude 05° 12'.99W (datum unknown).

Although the *Royal Anne* Galley lies close inshore in about 6m of seawater, the area is surrounded by rocks and large Atlantic swells make access difficult. The rocky seabed is a very dynamic environment with deep gullies and crevices obscured by thick kelp. No organic material has been recovered to date and the site seems to be artefact-bearing rather than containing any remaining ship's structure.

The purpose of the assessment is to allow English Heritage to make an informed judgment on best practice for field assessment and therefore to establish site stability and preservation potential. English Heritage's Marine Environmental Assessment programme is planned to enable commissioned projects to generate information that can contribute towards the objectives of the EU Culture 2000 project *Managing Underwater Cultural Heritage* (MACHU).

Because of a financial ceiling set by English Heritage the methodology for field assessment was a pared down version of the original strategy for field assessment and monitoring of the site which was presented in the Phase 1 desk-based assessment report (Camidge *et al* 2006).

The following objectives were successfully accomplished during the field assessment:

- A bathymetric survey was undertaken;
- A marine biological assessment was undertaken;
- A water sample was collected and analysed;
- Sediment samples were collected and analysed;
- Objects for monitoring dispersal (bricks and spheres) were installed on the site;
- Objects to monitor the biological degradation of timber were installed on the site

It is recommended that at least one recovery/inspection should be undertaken in 2010; the results from this will inform whether any further monitoring is required. The *Royal Anne* site lies within the draft Lizard Point Special Area of Conservation (dSAC) and the implications of this for future site management strategies should be discussed with Natural England.

2 Introduction

2.1 Project background

In 2005 English Heritage (EH) commissioned Historic Environment Projects, Cornwall Council (HE Projects), and Penzance-based maritime archaeologist Kevin Camidge to undertake a desk-based assessment of the *Royal Anne* Galley, a designated site under the Protection of Wrecks Act 1973. The desk-based assessment was Phase 1 of a proposed Marine Environmental Assessment (MEA) of the site. Following completion of the Phase 1 report (Camidge *et al*, 2006) which outlined a strategy for field assessment and monitoring of the site EH, commissioned a Project Design for field assessment (Phase 2) and monitoring (Phase 3), which was submitted at the end of January 2007 (Camidge *et al* 2007). Because of budgetary constraints EH subsequently asked HE Projects to re-cast the project design to encompass only a reduced Phase 2 field assessment with recommendations for further monitoring (Camidge *et al* 2008).

This report describes the results of the Phase 2 field assessment and includes the recommendations for future monitoring (Phase 3?). The report will allow English Heritage to make an informed judgment on best practice for field assessment and therefore to establish site stability and preservation potential. English Heritage's Marine Environmental Assessment programme is planned to enable commissioned projects to generate information that can contribute towards the objectives of the EU Culture 2000 project *Managing Underwater Cultural Heritage* (MACHU).

2.2 Aims and objectives

2.2.1 The overarching aim

As set out in the specification to undertake the Marine Environmental Assessment (MEA) the project will form one of a series of initiatives that will lead to the development of archaeological management plans for designated wreck sites that will inform English Heritage's future research, amenity and education developments for the benefit of the wider community (English Heritage 2004).

2.2.2 Objectives

The objectives of the Phase 2 field assessment were to:

- Georeference the existing site plan;
- Carry out a bathymetric survey;
- Collect water samples (reduced to a single take);
- Collect sediment samples;
- Install dispersal objects (bricks and spheres);
- Install objects to monitor the biological degradation of timber on the site;
- Carry out a marine biological assessment; and
- Produce a project report with recommendations for further monitoring.

2.3 Methodology

The Phase 1 desk-based assessment report contained a well-considered strategy for field assessment and monitoring of the *Royal Anne* Galley site (Camidge *et a*l 2006). Because of the financial ceiling set by EH many of the elements of this strategy had to be left out of the re-cast Phase 2 project design for field assessment (Camidge *et al* 2008), in particular using a

Nortek AWAC to monitor wave and tide data and monitoring corrosion of the two iron guns on the site, while other elements such as the biological survey were reduced in scope.

Because the site is designated under the Protection of Wrecks Act (1973), the collecting of sediment samples and the burying of the oak sample blocks required a licence to excavate on the site from English Heritage. A licence was also obtained from Defra for the deployment of the dispersal trial objects under the Food and Environment Protection Act Part II (FEPA) 1985, deposit of tracers and other materials in the sea, and the Coast Protection Act 1949. The Crown Estate and Natural England were consulted before the field assessment was undertaken.

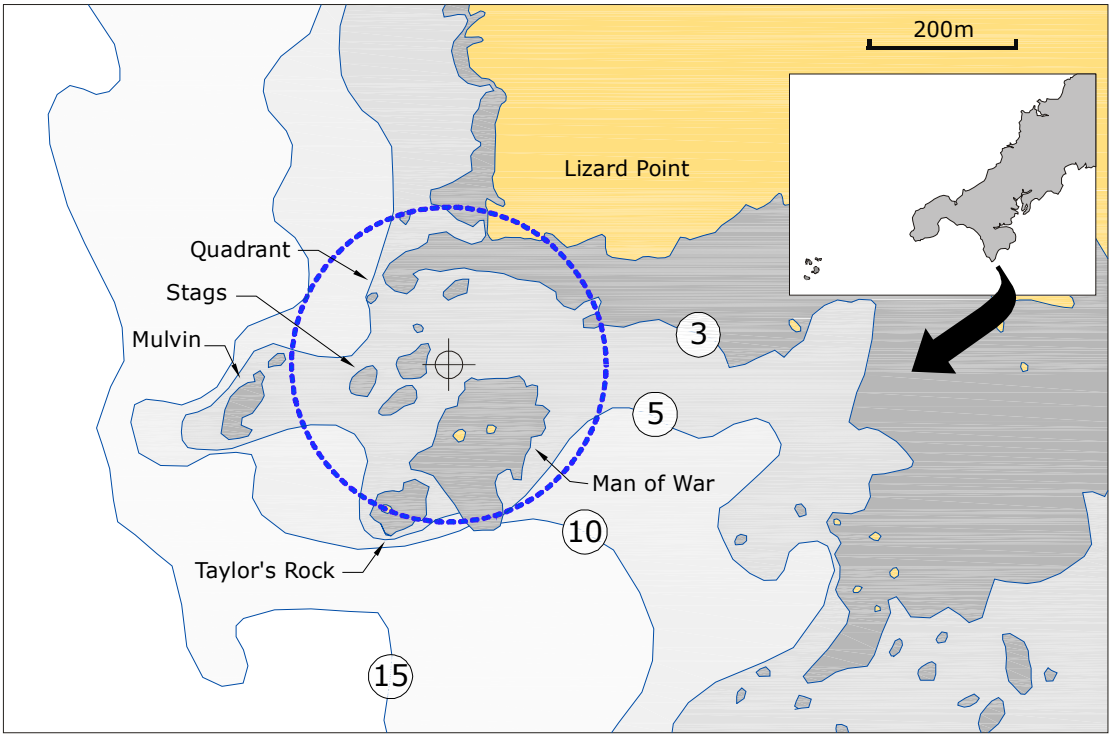

Fig 1 Location of the Royal Anne Galley designated wreck site off Lizard Point

In general the work was carried out according to the methodology set out in the Phase 2 project design but because the designated site of the *Royal Anne* Galley is subject to extremely dynamic sea conditions, significant swells, and considerable tides the methodology sometimes had to be modified to achieve results, and to minimise the possibility of incurring weather costs. It was not possible to carry out the field assessment in 2008 as originally planned because of the difficulty of synchronising personnel availability with suitable good weather windows and EH granted a variation to enable the work to be carried out during 2009.

It should be noted that in the past numerous visits by the Archaeological Diving Unit, St Andrews University (ADU), and more recently by the diving contractor, have failed to deploy surface supply divers on the site and that the number of days when conditions are suitable for diving on the site is limited to a maximum of 20 to 30 days per year. It is not uncommon for conditions to be unsuitable for periods of six to eight weeks, even in the summer.

The methodology for each aspect of the field assessment is described with the results in Section 3 below.

3 Field assessment

This section presents the various expert's reports, edited and formatted to conform to HE's house style.

3.1 Deployment

Kevin Camidge

3.1.1 Georeferencing the existing site plan

The existing site plan was not georeferenced. The only position given for the site was the centre of the designation. This was determined for the original designation before the days of readily available GPS units, so was likely to be an approximation only.

A position between the two small iron guns shown on the site plan was fixed using a taut shot line and marker buoy, the position of the marker buoy was determined using an EGNOS enabled GPS unit. The existing site plan was then rotated about this point until north was pointing up (0°). This should give an accuracy of approximately ±10m. If greater accuracy is required an acoustic tracking system linked to a RTK GPS unit will need to be employed.

The GPS position obtained (between the guns – see Figure 3 below) lies some 77m to the SSW of the centre of designation.

3.1.2 Dive team and deployment

Diving operations were undertaken on the site on the 15 and 16 of April 2009 by SeaStar Surveys Ltd (SeaStar), using an 8.2m RIB chartered from Dive Action Ltd of Porthkerris. Although the whole team was mobilised on the 15 April it was not possible to undertake any diving on that day as the sea conditions were unsuitable on the site. The following day, 16 April, sea conditions were far from perfect however the diving operations were nevertheless undertaken. As is often the case on this site, there was significant surge on the seabed due to swell, this makes taking measurements and photographs difficult.

Name	Role	Organisation
Gary Fox	Boat skipper	Dive Action Ltd
Toney Hillgrove	Dive Supervisor	SeaStar
Richard Gannon	Diver	SeaStar
Charles Sandercock	Diver	SeaStar
Laura Plastow	Standby diver	SeaStar
Mike Hall	Local pilotage	-
Kevin Camidge	Project supervision	Darkwright Archaeology
Miles Hoskin	Marine biologist	CMER

Fig 2 The on site team for the sampling and deployment phase of the project

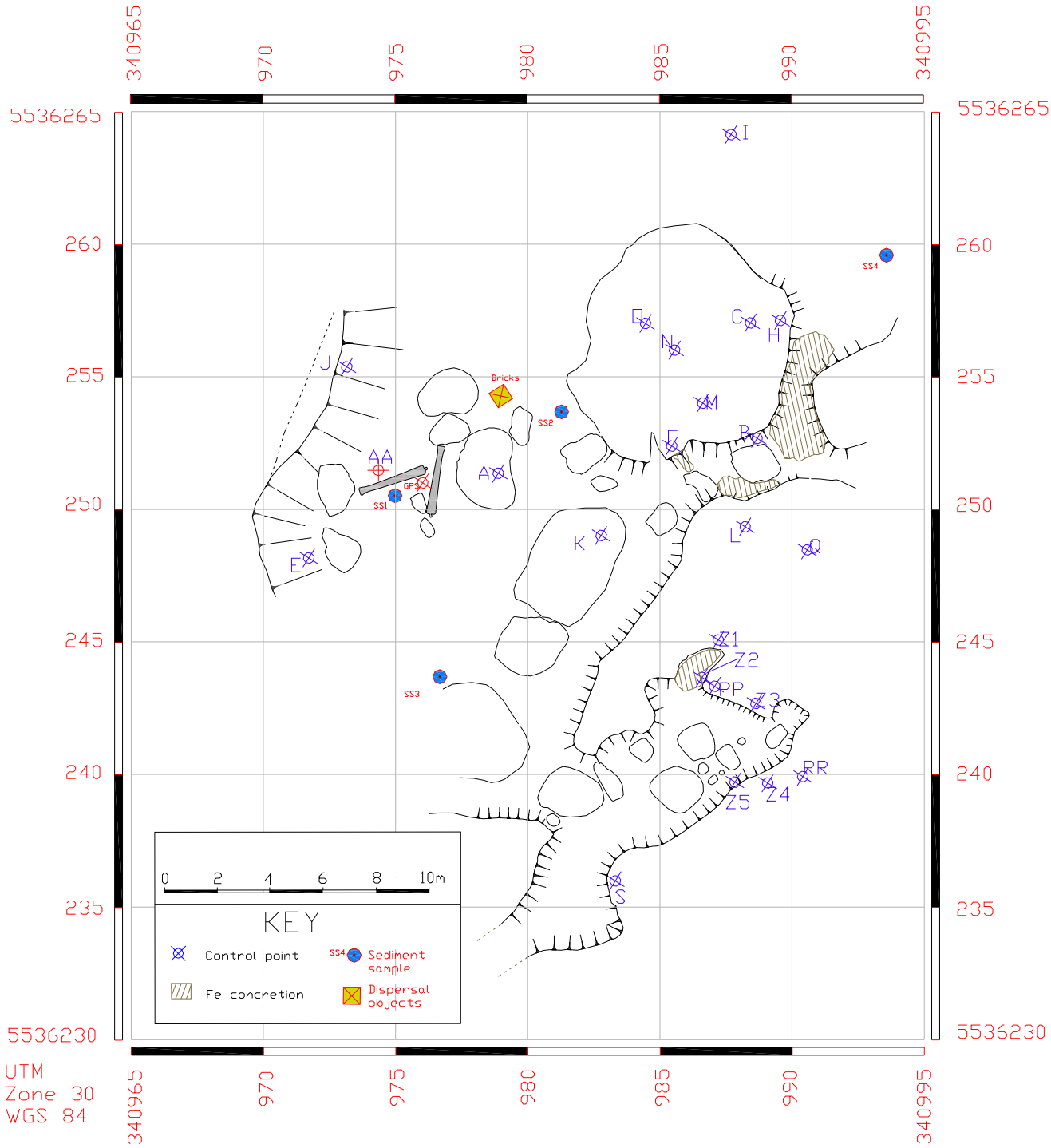

Fig 3 Georeferenced site plan showing the location of the sediment samples SS1-SS4 and the dispersal objects (bricks and spheres)

3.1.3 Sampling

One water sample and four sediment samples were taken. The sediment samples were analysed for sediment characterisation and geochemical properties. The sediment characterisation was undertaken by M G Canti of English Heritage, the geochemical analysis was performed by Derwentside Environmental Testing Services, Ian Panter of York Archaeological Trust provided interpretation of the geochemical results – see Sections 3/3 and 3.4 below.

Sample number	Position (UTM WSG84)	Depth	Date taken	Comments
WS1	340976E 5536251N	0.25m below sea surface	15.04.2009	Water
SS1	340974E 5536250N	0.10-0.20m below sea bed	16.04.2009	Sediment
SS2	340981E 5536253N	0.10-0.20m below sea bed	16.04.2009	Sediment
SS3	340976E 5536243N	0.10-0.20m below sea bed	16.04.2009	Sediment
SS4	340993E 5536259N	0.10-0.20m below sea bed	16.04.2009	Sediment

Fig 4 Table of sample locations – the sediment samples SS1-SS4 are also shown on the location plan (Fig 3)

Four sediment samples were taken on 16 April 2009 from the locations shown in Figs 3 and 4. These samples were taken by the dive team. First 0.10m of sediment were removed over a small area using a six-inch gauging trowel, then approximately 2kg of sediment were placed in a pre-labelled plastic tub using the trowel, the sediment collected came from between 0.10-0.20m below the seabed. Each sample was then divided into two 1kg samples for separate analysis of physical and chemical properties. The position of the sample locations on the seabed was established by measuring to the sample location from three of the fixed control points on the seabed (A, AA and K). These measurements were processed using Site Recorder GIS software.

3.1.4 Timber sample blocks

Over 400 objects have been recovered from excavation on this site to date. However, only one item of organic composition has been found (RAG 180 - this was a few small slivers of timber). Nothing of the fabric of the vessel itself has been identified. The most probable reason for the poor survival of timber and other organic material is the nature of the seabed on this site. The seabed consists mainly of hard rock gullies containing shallow deposits of coarse sand and cobbles to a maximum depth of 0.30m. These shallow deposits are unlikely to support the stable anoxic conditions favourable to the preservation of timber and other organic material. To test how timber survives on the site standard timber sample blocks were deployed on the site as part of the environmental assessment.

Previous studies (*Colossus*, MoSS and *Mary Rose*) have used a mixture of oak and pine blocks for these studies. But in each case the attack has been similar in the oak and pine samples, although the pine (being softer) is attacked slightly sooner and more severely than the oak. It is unlikely that any extra information would be gained by using both pine and oak blocks. It is highly likely that the *Royal Anne* Galley would have been constructed almost entirely from oak.

Eight oak sample blocks were deployed, four on the surface and four buried within the seabed sediments, in two separate locations on the site. These locations were the same as those sediment samples SS1 and SS2 were taken from, this allowed the blocks to be buried without

digging any additional holes, thus minimising the disturbance to the site. The buried blocks were labelled and buried approximately 0.20m deep. The oak blocks secured to the seabed surface were fastened to granite blocks each approximately 0.25 x 0.25 x 0.20m. The sample blocks were attached to the granite by means of cable ties and stainless steel rods, which were set into the granite block using polyvinyl resin. These surface blocks were placed in the same location as the buried sample blocks.

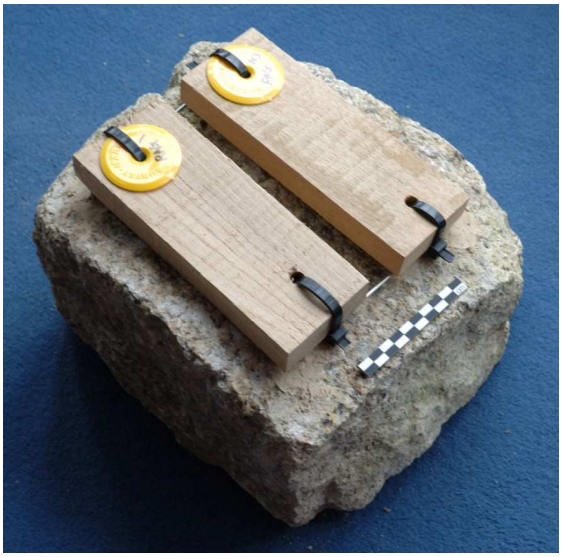

Fig 5 Oak samples secured to granite block using cable ties, scale = 0.10m

Fig 6 Stainless steel rods set into granite block using drilled holes and polyvinyl resin

The sample blocks will need to be recovered after 12 months exposure and analysed to determine the amount and nature of the degradation, identifying where possible the organisms responsible for the degradation. The amount of attack will be determined by weight loss and visually from X-rays of the recovered sample blocks.

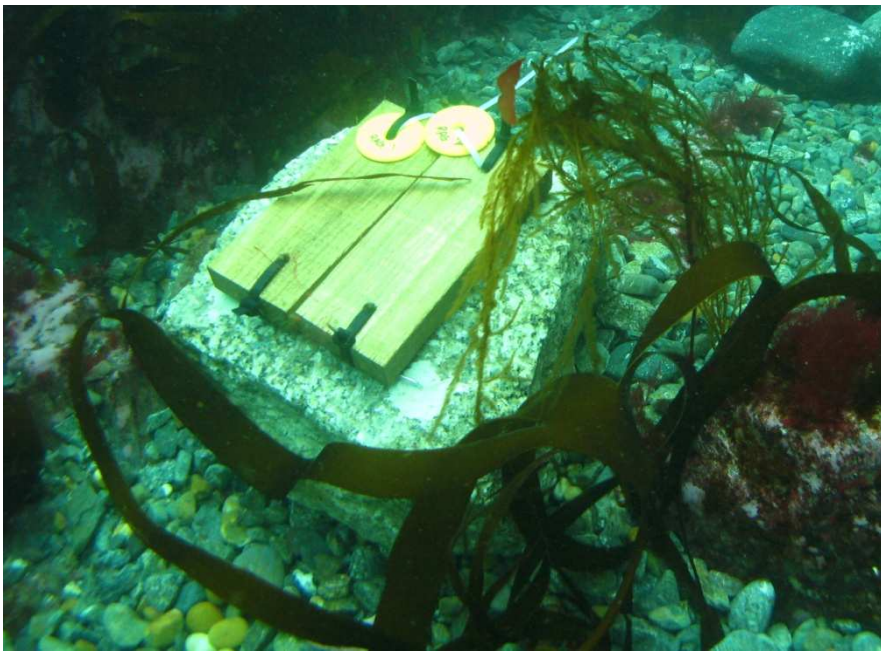

Fig 7

The surface sample blocks in place on the seabed – blocks 1&2 in location SS1

No	Weight (gms)	Location
1	286.9	SS1 – surface
2	262.1	SS1 – surface
3	215.4	SS2 – surface
4	244.4	SS2 – surface
5	221.3	SS1 – buried
6	303.9	SS1 – buried
7	242.3	SS2 – buried
8	217.7	SS2 – buried

Fig 8 Table showing the location of the eight oak sample blocks placed on the seabed

3.1.5 Dispersal objects

Workers on historic wreck sites have often reported the movement or 'disappearance' of artefacts exposed on the seabed. A number of attempts to quantify and measure these phenomena have been reported.

The usual technique is to place tracer objects on the seabed at known locations and to record their positions at set time intervals. At Kinlochbervie, practice golf balls and halved tennis balls respectively weighted with washers and bolts were used. These relatively light objects did not move far over an annual cycle; indicating relatively benign conditions over the period measured (Robertson 2004).

More recently, ceramic bricks have been deployed on the protected wreck sites *Hazardous Prize* and St Peter Port Harbour. The bricks were of two types, engineering and architectural bricks of different (but unknown) densities. The bricks were used whole, cut in half and into thirds. They were painted to aid location and tagged so that each brick could be individually identified (Holland 2005 and personal correspondence). This work is ongoing but latest reports indicate that some movement of bricks has been noted. Some bricks could not be relocated, indicating that they were missed by the divers, have become buried or have moved to outside the study area (Holland 2005).

This technique is a useful indicator of potential artefact mobility. It has the advantage of simplicity and low cost. This means it could be used widely on historic wreck sites and direct comparisons of the forces acting at the seabed of each site made. More sophisticated techniques involving active electronic or acoustic tracking of the tracer objects have been suggested; while this would reduce the incidence of 'lost' tracers it would involve considerable extra cost. As an example, acoustic ID tags which are detectable using sidescan sonar exist – but these cost in the region of £300 for each tag.

Two different tracer objects were employed in this trial. The first group were class 'A' engineering bricks conforming to BS EN 771-1. These have water absorption of ≤ 4.5% and a minimum density of 2200 kg/m^3. The particular bricks used here were 0.214 x 0.064 x 0.10m and weighed 3.3kg, giving an actual density of 2408 kg/ m^3. The bricks were painted yellow to aid visibility on the seabed and numbered (1-20) so that individual bricks can be tracked. Secondly, numbered white ceramic balls (steatite) of 51mm diameter and an average weight of 0.190kg, giving a density of 2735 kg/m^3 were used. It is hoped that these will model distribution of objects which are more easily rolled than the rectangular bricks. The starting location of the tracer objects is shown on Figure 3.

Both types of tracer object (20 of each) were placed on the seabed in a symmetric arrangement at position 340978E 5536253N (UTM zone 30 WGS84). The position of these objects will

need to be monitored and recorded at regular intervals, probably every 12 months. Once the objects start to move, their new locations will be plotted by measuring the distance and bearing from control point A. A radius of 5m around control point A will be searched thoroughly during each diving inspection, and a further radius from 5-10m will also be searched by divers but in less detail. This methodology may need to be modified during the trial once we establish the magnitude of the displacements after the first inspection.

Fig 9 The numbered steatite balls prior to deployment on the seabed

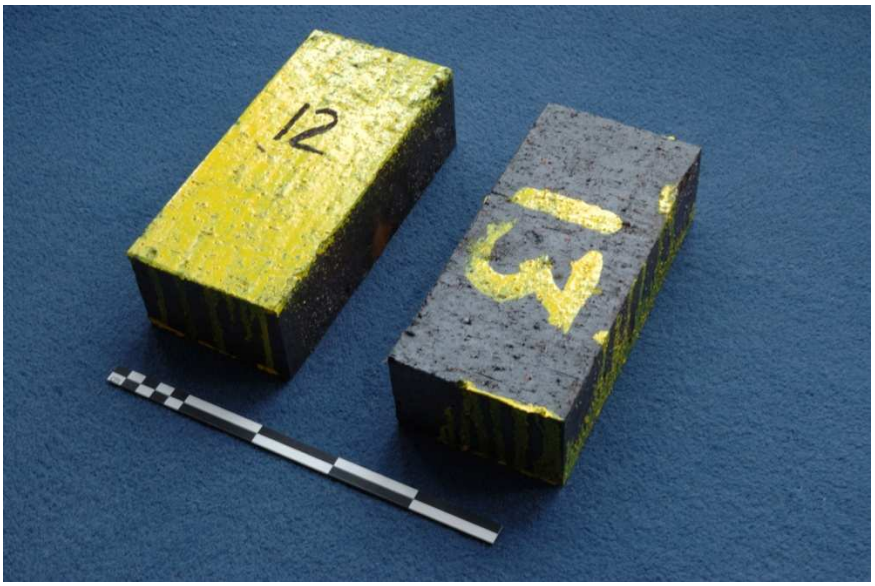

Fig 10 The numbered engineering bricks prior to deployment on the seabed

Fig 11 The steatite balls and engineering bricks (20 of each) in place on the seabed

3.2 Bathymetric survey

3.2.1 Introduction

The purpose of the bathymetric survey is to measure depth and chart the seabed terrain**,** it was undertaken by SeaStar Survey Ltd on 24 September 2009. The survey was mobilised on as good as a weather forecast as it was possible to achieve (very calm conditions in the channel). Sea conditions were initially good but deteriorated as the day progressed. The bathymetric survey was completed in a single day. The metadata for this survey is detailed in Appendix 2 below.

3.2.2 Methodology

SeaStar considered it necessary to redesign the survey to make it more weather resilient and to minimise the possibility of weather costs, therefore they did not use the equipment specified in the project design, and changed the vessel and the equipment (S Dewey pers comm.).. Positioning was originally to be by RTK GPS; the survey in fact used a differential GPS system which resulted in some loss of positional accuracy. The survey was also originally specified to use a motion reference unit to correct for the motion of the survey vessel; in fact SeaStar used a self contained Ceeducer survey echo sounder which did not have a motion reference unit fitted. While SeaStar felt they have delivered better data using a system of a much higher specification, this would have undoubtedly incurred significant weather delays.

Fig 12 Sea conditions in the survey area

Fig 13 The Ceeducer echo sounder unit onboard the survey vessel Mytilus

3.2.3 Results

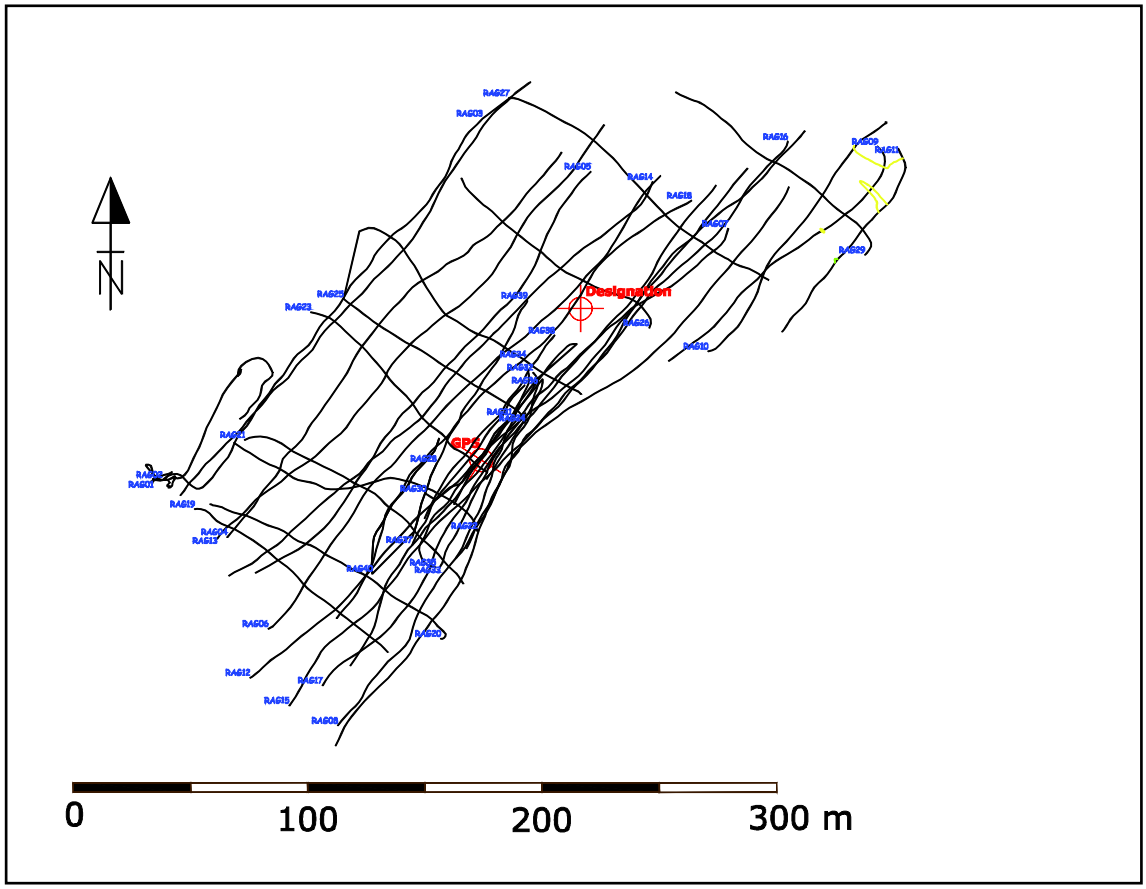

Fig 14 Track plot of the SeaStar bathymetric survey

The above track plot (Fig 14) shows the survey lines used to collect the bathymetric data. The position of the centre of the designation and the GPS position taken between the two guns on the site are also shown for reference. The survey lines are curved, and in some cases truncated due to the need to avoid the various shallow rocks and reefs around the site.

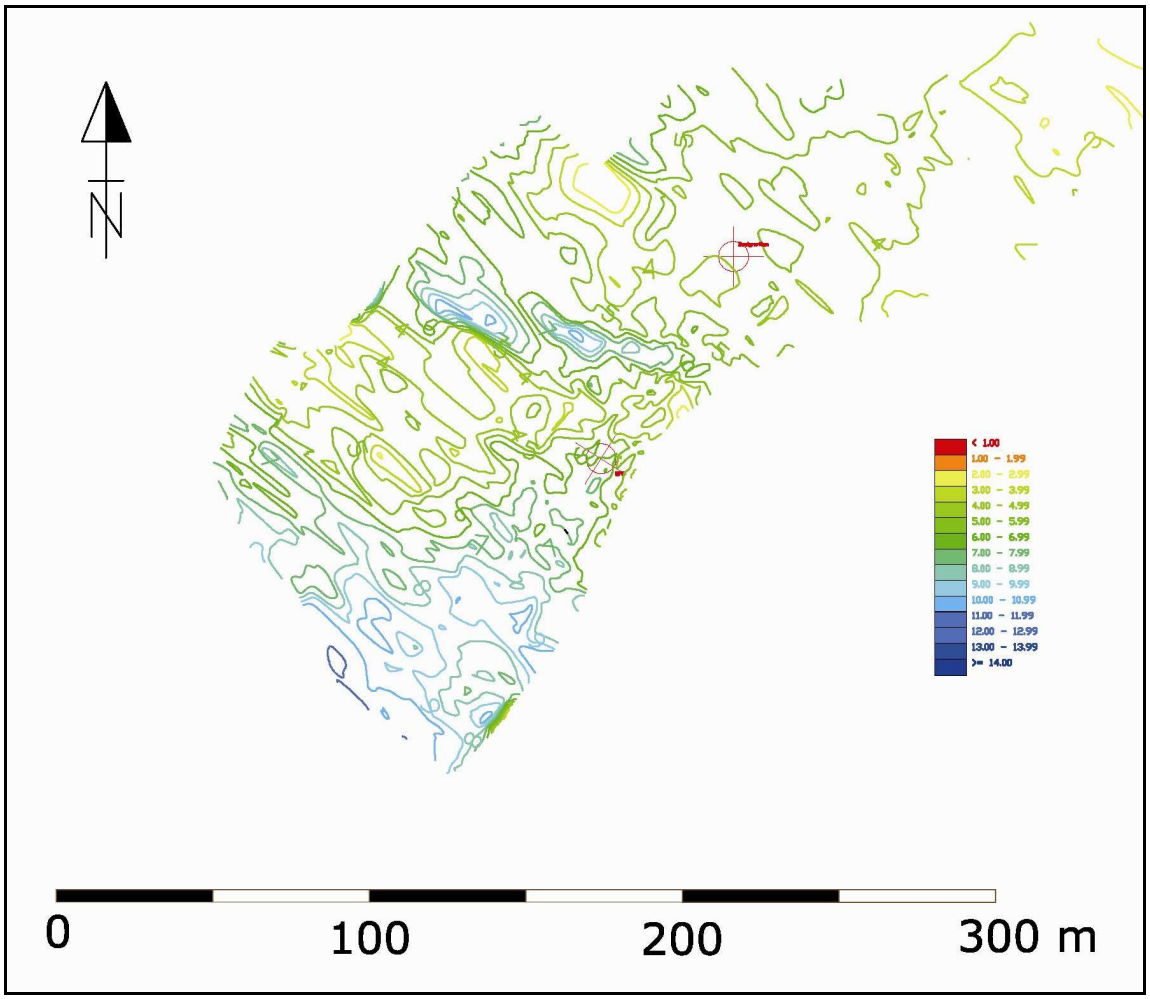

Fig 15 Contour plot at 1m vertical intervals, produced by SeaStar. It was produced using Hypack survey software

The contour plot (Fig 15) does not reproduce well at the size required to fit onto the pages of this report. A more detailed version accompanies the report as a PDF file on CDROM.

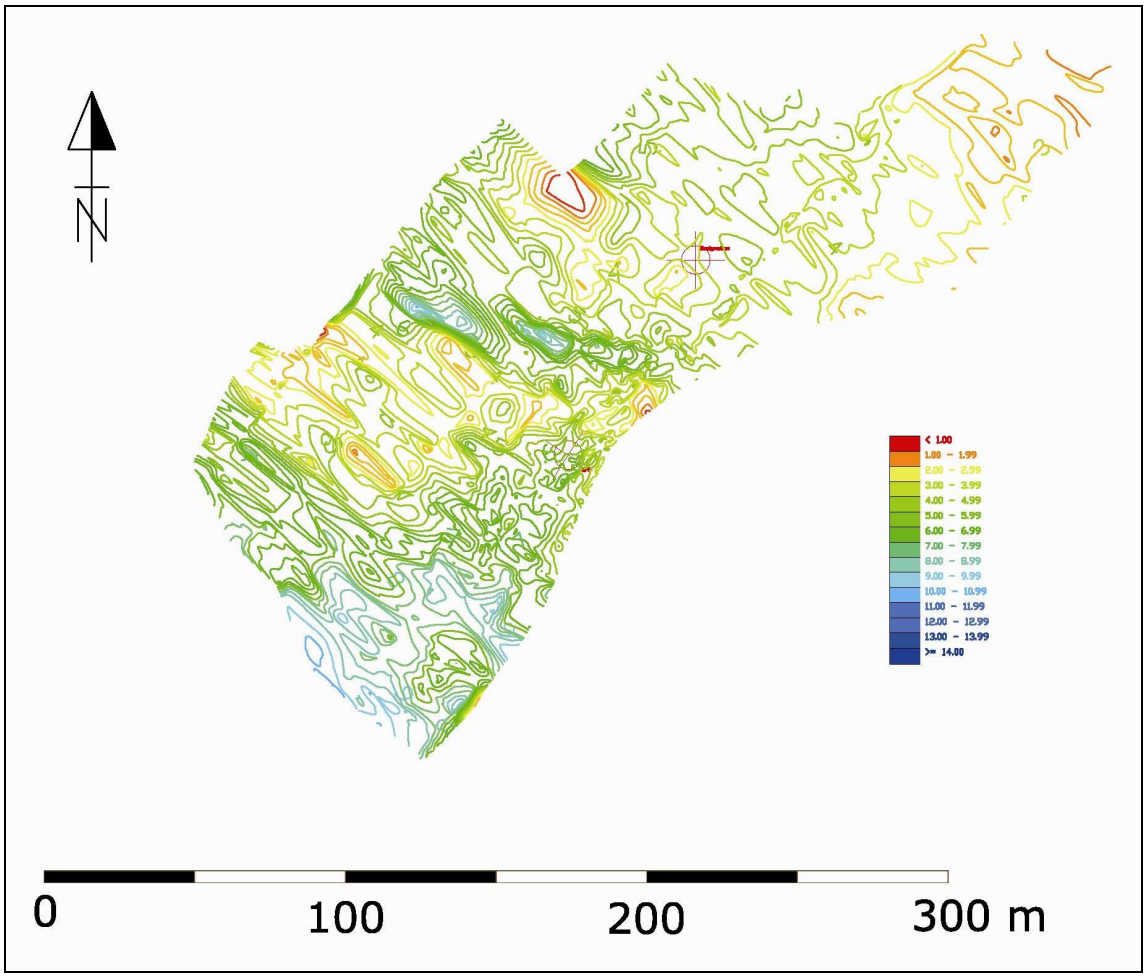

Fig 16 Contour plot at 0.5m vertical intervals, produced by SeaStar using Hypack survey software

The contour plot (Fig 16) does not reproduce well at the size required to fit onto the pages of this report. A more detailed version accompanies the report as a PDF file on CDROM.

Given the limitations of the equipment used and the sea conditions the 1m vertical spacing contour plot is probably the most representative of the seabed bathymetry around the site.

3.3 Geochemical assessment of sediment and seawater samples

Ian Panter, Principal Conservator, York Archaeological Trust, YAT Report 2009/50

3.3.1 Methodology

As part of the marine of the marine environmental assessment for the *Royal Anne* Galley designated site, four sediment samples and one water sample were collected by divers from the locations shown above in Figure 3. The sampling strategy involved the removal of the top 0.10m of sediment, collecting samples from between 0.10m and 0.20m below the sea bed.

Samples were collected in containers provided by Derwentside Environmental Services and despatched to their laboratory in Co Durham for analysis (see Appendix 1). A single water sample was collected at a depth of 0.25m below the surface, directly over the guns (Kevin Camidge pers comm).

3.3.2 Results

The samples were submitted to standard tests for assays of a range of parameters that can be used to assess the characteristics of the burial environment. The full results are listed in the appendix below, with the most important parameters highlighted.

pH

All samples are near neutral. The highest pH value, 7.8, was obtained from the seawater sample, whilst the four sediment samples gave near identical values of between 7.1 and 7.3.

Dissolved oxygen

Low oxygen levels ranging from 0.2mg/litre to 0.8mg/litre were measured in the sediment samples, and the seawater sample recorded 9.4mg/litre.

Sulphide/sulphate

Sulphide and sulphate species were detected in all four sediment samples. The tests were not performed on the seawater sample. The highest concentration of sulphide was measured in sample 4 at 16,000μg/litre and the lowest, 830μg/litre from sample 1. Sample 4 also recorded the highest concentration of sulphate, 3200mg/litre, whilst sample 2 produced the lowest level of sulphate at 2400mg/litre.

Nitrites/Nitrates

All values were less than 0.10mg/litre and hence it can be concluded that there are no appreciable concentrations of either nitrates or nitrites in either the seawater or the sediments.

Ferrous iron

Only two sediment samples, 1 and 4, produced measurable concentrations of ferrous iron of 0.19mg/litre and 0.79/mg/litre respectively. The other two samples were below the detection level of less than 0.10mg/litre.

Phosphate

Phosphate was detected in sediment samples 2, 3 and 4 at 0.45mg/litre, 1.7mg/litre and 2.7mg/litre respectively. Sediment sample 1 and the seawater sample gave results below the detection levels (less than 0.10mg/litre).

Ammoniacal nitrogen

Ammoniacal nitrogen was detected in all four sediment samples with values ranging between 2.7mg/litre (sample 1) to a high of 55mg/litre (sediment 4). No test was performed on the seawater.

3.3.3 Discussion

The geochemical assay of four sediment samples has helped characterise the nature of the burial environment at the wreck site of the *Royal Anne* Galley. The aim of this investigation was to identify which redox (oxidation-reduction) sensitive chemical species were present in the sediments which would determine whether the burial environment was conducive to continued preservation of the remains and artefacts associated with the vessel. The principle chemical species used to characterise a burial environment are oxygen, iron (ferrous and ferric ions), nitrogen (nitrate and nitrite) and sulphur (sulphate and sulphide). These chemical species are utilised by organisms during the oxidation of organic matter based on the availability of the species and the potential energy yield. The maximum energy yield is obtained from oxygen (thereby resulting in the highest level decay) and the lowest energy yield coming from the utilisation of methane. Therefore degradation will occur in anoxic deposits, but at a much slower rate as the energy yield is much lower.

The presence/absence of each of these can be used to define the redox environment of the seabed sediments thus:

Depth ↓

Redox species present	Redox Environment
Oxygen	Oxidising
Nitrate	Mildly reducing
Iron and Sulphate	Mildly reducing
Methane	Highly reducing

Fig 17 Redox environment of seabed sediments

Optimum preservation is to be found in those sediments that are defined as "highly reducing", however, long-term preservation is still possible where conditions are "mildly reducing".

The highest concentration of oxygen (9.4mg/litre or 9.4ppm) was recorded from the seawater sample, but oxygen levels were much lower in the sediments, where the average concentration was 0.53mg/litre or 0.53ppm. It is possible that contamination from oxygen has occurred during sampling and processing; however, these values compare favourably with recent studies which found that oxygen saturation reached zero percent at 10cm below the sediment surface (Gregory, 2004). Given such low levels of oxygen, the sediments can be defined as near-anoxic.

High concentrations of sulphate (2400mg/litre to 3200mg/litre) and sulphide (830µg/litre to 16,000µg/litre) species, along with negligible levels of nitrates and nitrates (all less than 10mg/litre) suggest that the dominant process in the sediments is sulphate reduction. This process is often the dominant reaction in seabed sediments due to the high levels of sulphate to be found in seawater (Gregory et al, 2008). Oxidation of the sulphide to sulphate during sample processing may account for the relatively high levels of sulphate compared to the sulphide concentrations. Hence the burial environment can be defined as "mildly reducing" where Sulphate Reducing Bacteria (SRB) are the principle agents of decay (the presence of ferrous iron in samples 1 and 4 also support this definition as ferrous iron is only formed under reducing conditions) (Andrews *et al* 2004).

Such bacteria require anoxic conditions, the presence of sulphates and essential nutrients for growth. Potential sources of nutrients will be both natural (including algae and other micro organisms) and any organic remains and artefacts associated with the wreck. During growth,

the SRBs will oxidise organic matter, using the sulphates as a source of energy. As the energy yield is low degradation will proceed at a very slow rate though.

Metal artefacts, including iron and copper based ones may be affected by SRB activity:

- SRBs will depolarise the cathodic zones within the iron by consuming hydrogen ions, and corrosion will continue even in anoxic conditions
- Production of hydrogen sulphide gas accelerates corrosion of copper based alloys by a process of substitution with sulphide for the more oxidised corrosion products that formed on copper alloys in aerated seawater (Florian 1987).

The stability of metals will be determined by the pH and the redox potential of the burial environment. All four samples were neutral, with three samples having a pH of 7.3 (samples 1, 2 and 3) and the other having a pH of 7.1. The seawater was slightly alkaline at 7.8. Whilst in situ redox potentials weren't measured, the geochemical assay demonstrates that reducing conditions exist, and under these conditions (neutral and reducing) it could be expected that iron could be under "passivating" conditions. Corrosion can occur if conditions become highly acidic and oxygenated (promoting the formation of soluble ferric Fe^{3+} ions), or highly acidic and reducing that favour the formation of soluble ferrous (Fe^{2+}) ions. Copper based alloys and other metals are likely to under similar benign conditions too.

The likely source of the ammoniacal nitrogen is as a result of decomposing phytoplankton (Andrews *et al* 2004).

In conclusion the geochemical assay of four samples indicates that reducing conditions exist at a depth of between 10 and 20cm at the wreck site of the *Royal Anne*. These conditions are conducive to the continued preservation of artefacts and structural elements that remain buried at the site. However, as the dominant process in the sediments has been identified as sulphate reduction through the activity of sulphate reducing bacteria, ongoing degradation is occurring albeit at a very slow rate. If the cultural evidence remains buried there is nothing to indicate that conditions could change that could affect preservation, from a chemical perspective, although oxygenation is possible through bioturbation by invertebrates or seabed currents removing the sediment overburden.

3.4 Sedimentary examination of seabed samples

M G Canti, English Heritage, Fort Cumberland, Eastney, UK. PO4 9LD

3.4.1 Introduction

Four loose sediment samples from the *Royal Anne* Galley wreck site were submitted for analysis. The aim was to have a simple characterisation of the sediments at the site, as outlined in the project design (Camidge *et al* 2008).

3.4.2 Methodology

The sediments were sieved to produce particle size analysis curves using the approach outlined in Canti (1991). In all cases there was too little fine sediment to continue the curve below 45μm.

Subsamples of the finer sediments were examined under reflected light and also the polarising microscope for mineral identification.

3.4.3 Results

Figure 1 shows the particle size results as a series of cumulative curves. These can be most simply interpreted as large proportions of material where the curve is steep and smaller amounts where it is flatter (see Canti 1991). In all cases the bulk of the *Royal Anne* Galley

material is stones larger than 10 mm. These are subangular to rounded pebbles of mixed lithology, the largest being around 5 cm in diameter.

The 2 mm -250 μm fraction was examined under reflected light and consisted of about 70 % shell and 30 % rock fragments in samples 2, 3 and 4. Sample 1 was about 50 % iron oxides, 30 % shell and 20 % rock fragments.

The <250 μm fraction was examined in a refractive liquid under polarised and cross polarised light. Samples 2, 3, and 4 consisted of about 95 % shell, with 5 % of rock fragments, quartz and other minerals (green amphiboles, clear amphiboles and chlorite). Sample 1 was about 50 % opaque iron oxides, the remaining 50 % being similar composition to samples 2, 3 and 4. The iron oxides in SS1 are likely to have come from the breakdown of one of the iron-rich nodules occasionally found amongst the pebbles.

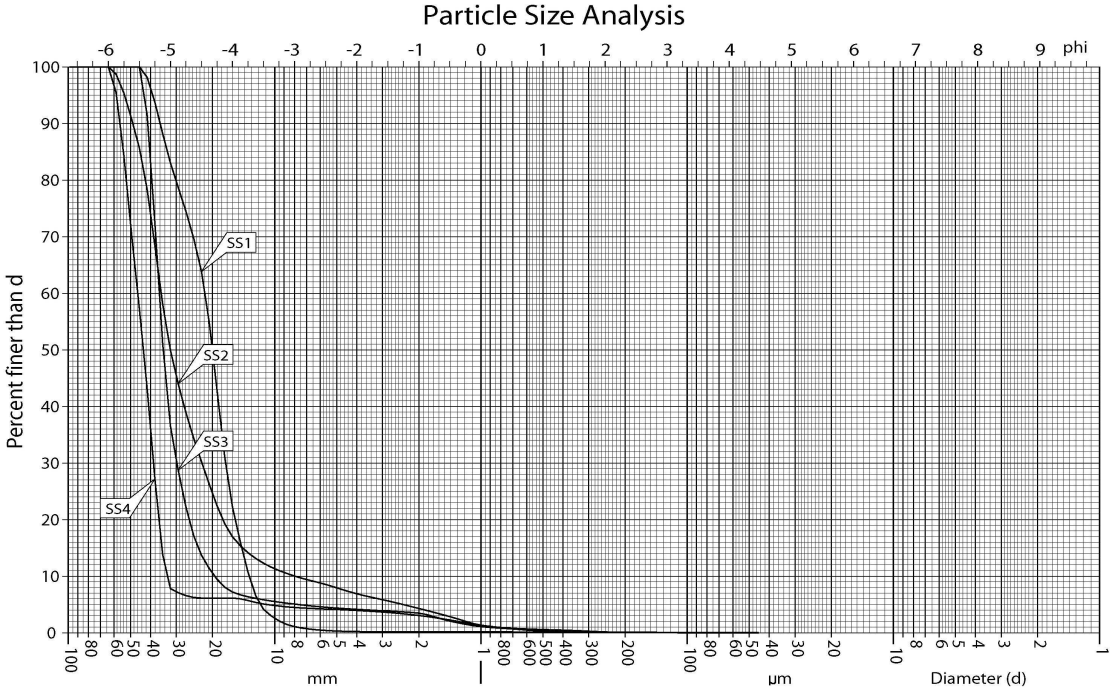

Fig 18 Particle size results for all four sediment samples

3.4.4 Conclusions

The four samples are fundamentally similar, being composed of large, quite rounded stones with a tiny proportion of shell, rock fragments and associated minerals. The seabed sediments of the area are commonly made of these types of coarse pebbles (Kevin Camidge pers comm), so the high energy sorting is clearly a natural result of the turbulent conditions.

3.5 Marine biological survey

Miles Hoskin, CMER, and Charles Johns

3.5.1 Introduction

The need for a marine biological survey of the *Royal Anne* Galley site was identified in the Phase 1 report (Camidge *et al* 2006). It was envisaged that marine biological knowledge of the site would *"enhance understanding of the environmental conditions affecting the preservation of the archaeological material"*. To this end a survey was proposed to characterise and quantify flora and fauna, including seasonal variations, in a 25m x 25m area centred on the designated position of the *Royal Anne* Galley.

The rationale and plan for a marine biological were further progressed in the project design for the Phase 2 field assessment and Phase 3 monitoring (Camidge *et al* 2007). It was recognised that marine biological knowledge would be useful if an Environmental Impact Assessment was required as part of the licensing procedures under the Food and Environment Protection Act (FEPA) 1984, and to know if any habitat or species present at the site is prioritised for statutory protection via measures such as the Wildlife and Countryside Act (1981) or the UK Biodiversity Action Plan.

It was also hypothesised that if marine archaeological items (eg iron cannon and cannon balls) were found to support conspicuous species that were absent or rare in adjacent natural habitats, this might help locate other undiscovered items that are concealed by biological over-growth.

3.5.2 Methodology

The scope of the biological assessment, like that of the archaeological work, was reduced in scope from that originally envisaged in the project design for field assessment and monitoring (Camidge et al 2007). The survey plan that emerged began with an initial reconnaissance by marine biological divers to assess the range of broad habitat-types present within the 25m x 25m survey area (potentially including habitats provided by archaeological items). It was intended that this exercise would then enable the identification of appropriate methodologies for quantitative sampling of the species present in these habitats. The main survey was to involve stratified random sampling of the species present in each of the major habitat-types identified via the initial reconnaissance.

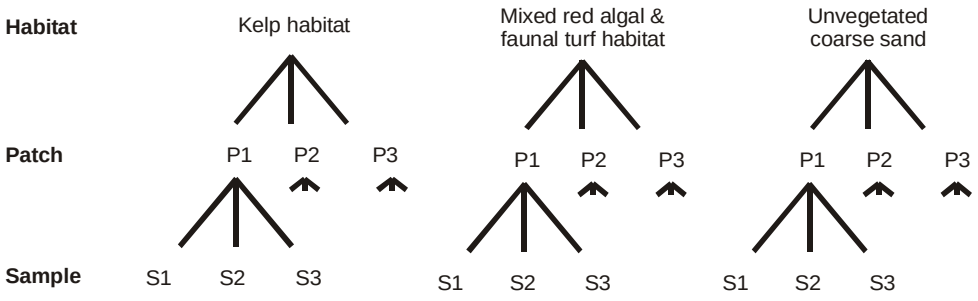

Fig 19 Representation of a hypothetical scheme of stratified sampling for a site with three broad habitat-types

The data obtained from this survey was be analysed statistically to assess ecological variation within and among habitat-types and to characterise the main 'biotopes' present at the site (the description of a 'biotope' combines information about the physical nature of the habitat and the species it supports). These biotopes were then e compared to established biotopes in the Joint Nature Conservancy Council's (JNCC) Marine Habitat Classification for Britain and Ireland (Connor *et al.* 2004).

3.5.3 Summary of results

The main habitat present at the *Royal Anne* site comprises very stable horizontal or sloping rock surfaces on bedrock outcrops and large boulders. CMER estimated that this habitat covers ~60% of the *Royal Anne* Galley site. Other important habitats that were present, but which were not surveyed were *(i)* very stable vertical or overhung bedrock and boulder surfaces (~20% of the total area) and *(ii)* densely-packed, mobile pebbles, cobbles and occasional small boulders in rock gullies (~20% of the total area).

The survey of the main habitat present at the site recorded the presence and relative abundance of 39 species of flora and fauna. The flora comprised 20 species of algae, including 14 species of red algae (Division Rhodophyta) and 6 species of brown algae (Class Phaeophycae). The fauna comprised representatives from seven invertebrate phyla.

Fig 20 Pebble and cobble habitat at the Royal Anne Galley site (photo CMER)

Ecologically, the most conspicuous feature of the survey area was a dense forest of kelp. This mainly comprised *Laminaria hyperborea* and to a lesser extent *L. digitata.* Two other kelp species, *Sacchoriza polyschides* and *Alaria esculenta* were also present. On rock surfaces beneath the kelp forest there was a dense and diverse turf of red algae and small animals (*e.g.* sponges, bryozoans, ascidians, anemones, hydrozoans, gastropods, etc). Scattered amongst the kelp forest were occasional larger animals such as the sea urchin *Echinus esculentus* and the brown crab *Cancer pagurus.*

Statistical comparison of survey data with similar data for established biotopes in the JNCC Marine Habitat Classification did not reveal a precise match with any such biotope. The *Royal Anne* Galley site biotope did, however, share many compositional similarities with four closely-related types of high-energy, infralittoral rock biotope that were characterised by the presence of *L. hyperborea.* One of these established biotopes typically occurred on rock habitats subject to scouring from mobile sediments. The similarity between this biotope and the *Royal Anne*

Galley site biotope indicates that parts of the area surveyed are occasionally subject to scouring via movements of adjacent pebbles, cobbles and small boulders during storms.

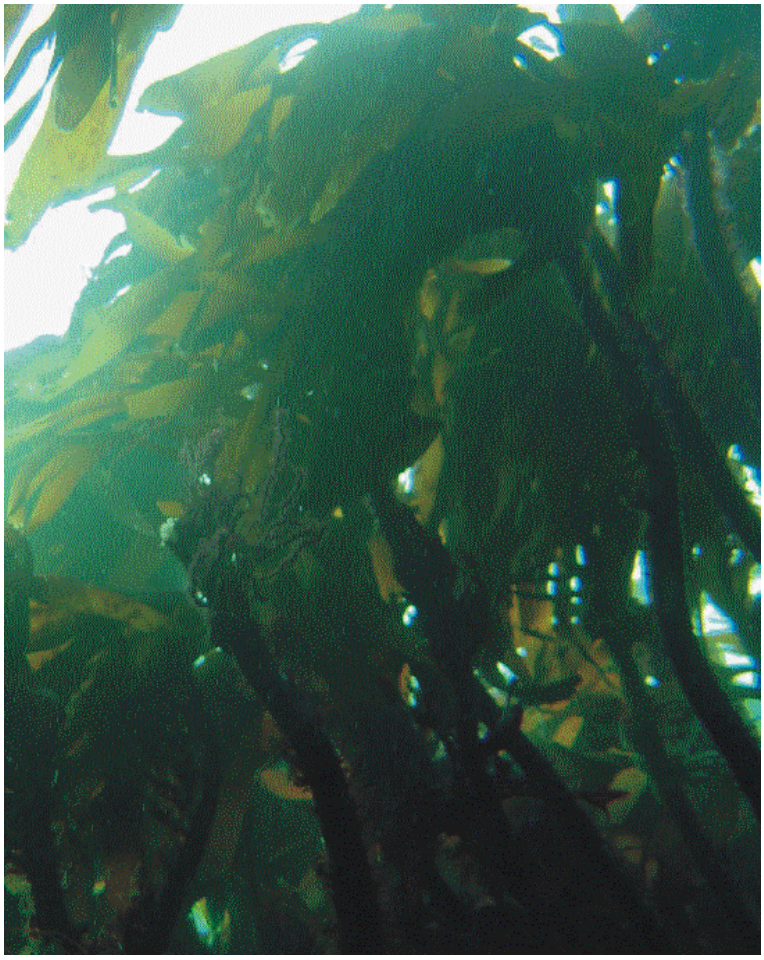

Fig 21 Forest of kelp Laminaria hyperborean at the Royal Anne Galley site (photo: CMER)

Kelp biotopes like that recorded at the *Royal Anne* Galley site are common on exposed western coasts from the Shetland Islands to the Isles of Scilly, and also on exposed coasts in north-east England. This is because the physical environmental conditions that favour this type of biotope are very common in the UK and Ireland and its characteristic species generally have wide geographic distributions.

Based on published species lists for the four established biotopes most similar to the *Royal Anne* Galley biotope, there may be 60 to 90 additional species present within this biotope that were not recorded during the present survey. Only one of these potential additional species – the trumpet anemone *Aiptasia mutablis* – is recognised as a species of conservation concern, but it does not have any statutory protection.

A recent statutory development of relevance to the assessment of the site's importance for nature conservation is Natural England's plan to have the wider marine area around the site designated as a Special Area of Conservation under the EU Habitats Directive (the draft Lizard Point SAC - dSAC). Natural England (NE) is the statutory nature conservation advisory body for England. The purpose of this SAC will be to protect reef habitats in the area, including that present at the *Royal Anne* Galley site.

Had it not been for the Lizard Point dSAC, CMER would have been determined that the *Royal Anne* site was only of low importance for nature conservation based on the habitats and species present, or likely to occur there. In the event of the designation of the Lizard Point SAC, the *Royal Anne* Galley site will become moderately more important. Whilst SACs are very important statutory sites (significant in a European context), ecological preservation of the *Royal Anne* site will not be essential for maintaining the integrity of the Lizard Point SAC because the habitats and species it supports are present elsewhere within its boundary and in several other SACs in SW England.

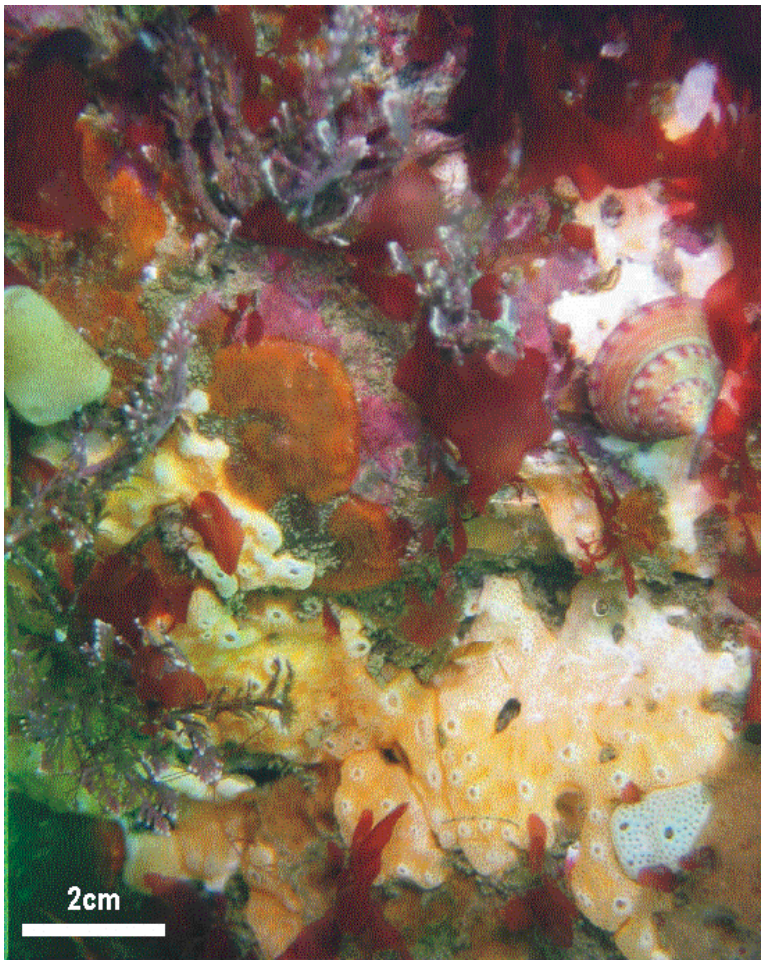

Fig 22 Example of the turf of animals and small algae on the rock substratum beneath the kelp forest at the Royal Anne galley site (photo: CMER)

General classification	Species name	SACFOR abundance	Common name
Phylum Ochrophyta, Class Phaeophyceae	*Alaria esculenta*	Occasional	Dabberlocks
‘’	*Desmarestia ligulata*	Occasional	
‘’	*Desmarestia viridis*	Occasional	
‘’	*Laminaria digitata*	Common	Oarweed
‘’	*Laminaria hyperborea*	Abundant	Tangle or Cuvie
‘’	*Saccorhiza polyschides*	Occcasional	Furbelows
Subkingdom Biliphyta, Division Rhodophyta	*Calliophyillis flabellata*	Occasional	
‘’	*Callophyllis laciniata*	Rare	
‘’	*Chondrus crispus*	Rare	Charageen
‘’	*Corallina officinalis*	Occasional	
‘’	*Cryptopleura ramosa*	Occasional	
‘’	*Delesseria sanguinea*	Occasional	Sea beech
‘’	*Dilsea carnosa*	Frequent	Red rags
‘’	*Drachiella spectablis*	Frequent	
‘’	*Lithophyllum* spp.	Frequent	Encrusting coralline alga
‘’	*Lomentaria articulata*	Occasional	

General classification	Species name	SACFOR abundance	Common name
"	*Membranoptera alata*	Occasional	
"	*Palmaria palmata*	Abundant	Dulse
"	*Phycodrys rubens*	Common	Sea oak
"	*Polysiphonia stricta*	Frequent	
Phylum Porifera, class Demospongiae	*Antho coriacea*	Rare	
Phylum Porifera, Class Calcarea	*Scypha ciliata*	Frequent	Purse sponge
Phylum Bryozoa, Class Gymnolaemata	*Electra pilosa*	Frequent	
"	*Escharoides coccinea*	Occasional	
"	*Membranipora membranacea*	Occasional	
Phylum Cnidaria, Class Hydrozoa	*Tubularia indivisa*	Rare	
Phylum Cnidaria, Class Anthozoa	*Corynactis viridis*	Common	Jewel anemone
"	*Urticina felina*	Occasional	Dahlia anemone
Phylum Crustacea, Order Decapoda	*Cancer pagurus*	Frequent	Brown crab
Phylum Mollusca, Class Gastropoda	*Calliostoma zizyphinum*	Occasional	Painted topshell
"	*Helcion pellucidum*	Common	Blue-rayed limpet
"	*Patella vulgata vulgata*	Occasional	Common limpet
Phylum Echinodermata, Class Asteroidea	*Asterias rubens*	Occasional	Common starfish

General classification	Species name	SACFOR abundance	Common name
Phylum Echinodermata, Class Echinoidea	*Echinus esculentus*	Occasional	Common sea urchin
Phylum Echinodermata, Class Asteroidea	*Henricia oculata*	Frequent	Bloody Henry starfish
Phylum Chordata, Class Ascidacea, Family Didemnidae	*Tridemnum cereum*	Rare	
Phylum Chordata, Class Ascidacea, Family Didemnidae	*Lissoclinum perforatum*	Rare	
Phylum Chordata, Class Ascidacea, Family Polyclinidae	*Synoicum incrustans*	Rare	
Phylum Chordata, Class Ascidacea, Family Syelidae	*Botryllus schlosseri*	Rare	Star seasquirt

Fig 23 Species and SACFOR abundances on stable horizontal or sloping rock surfaces in the survey area at the Royal Anne Galley site (statistical comparisons of data on the relative abundances of species at the Royal Anne Galley site with similar data for candidate biotopes were done by calculating a multivariate dissimilarity measure for each pairwise comparison, the multiple variables being the SACFOR abundances of the different species at the site). These analyses were done using statistical software PRIMER v6 (Clarke and Gorley 2006).

4 Recommendation for future monitoring and sample recovery

At least one recovery/inspection should be undertaken in 2010, the results from which will inform whether any further monitoring is required. A dive team for two days will be needed. The oak sample blocks were originally designed to be recovered at 12 and 24 months (see Project Design, Camidge *et al* 2008) but the difficulties encountered so far in accessing the site suggest that a single recovery would be more realistic.

Tasks for 2010:

- Check control points, replace as necessary and label.
- Locate and recover oak sample blocks (surface and buried)
- Locate and map positions of dispersal objects (bricks and steatite balls)

In the light of the Lizard Point dSAC, proposed archaeological monitoring and management strategies for the *Royal Anne* Galley site should be discussed with Natural England who will advise on the scope and nature of any future marine biological investigations required to asses the implications of the monitoring and management strategies for the Lizard Point SAC.

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6 Project archive

The HES project number is **2008023**

The project's documentary, photographic and drawn archive is housed at the offices of Historic Environment, Cornwall Council, Kennall Building, Old County Hall, Station Road, Truro, TR1 3AY. The contents of this archive are as listed below:

1. A project file containing site records and notes, project correspondence and administration and an information file containing copies of documentary/cartographic source material (file no 2008023).
2. Digital photographs stored in the directory ..\Images\Sites\Maritime\Royal Anne Galley Phase 2 Field Assessment 2008023
3. This report text is held in digital form as: G:\CAU\HE Projects\Sites\Maritime\ Royal Anne Galley MEA Phase 2 Draft Report

7 CD-Rom

The CD-ROM accompanying this report contains the following folders:

Photos of the dispersal objects and timber sample blocks

Photos of the bathymetric survey

Photos of the field deployment

Bathymetric survey contour plots (SeaStar Survey Ltd)

Bathymetric survey track plot (SeaStar Survey Ltd)

Bathymetric survey raw data (SeaStar Survey Ltd)

Georeferenced site plan

8 Appendix 1 Results from Derwentside Environmental Testing Services

dets
Derwentside Environmental Testing Services

UKAS
TESTING
2139

Certificate of Analysis

Date: 07/05/2009

Certificate Number: 09-27202

Client:	Mr Camidge 10 Tolver Place Penzance TR18 2AD
Our Reference:	09-27202
Client Reference:	
Contract Title:	Royal Anne Galley
Description:	5 water samples
Date Received:	22/04/2009
Date Started:	28/04/2009
Date Completed:	07/05/2009
Test Procedures:	Identified by prefix DETSn, details available upon request.
Notes:	Observations and interpretations are outside the scope of UKAS accreditation * denotes test not included in laboratory scope of accreditation # denotes test that holds MCERT accreditation, however, MCERTS accreditation is only implied if the report carries the MCERTS logo $ denotes tests completed by an approved subcontractor I/S denotes insufficient sample to carry out test U/S denotes that the sample is not suitable for testing DETSM denotes tests carried out by DETS Midlands laboratory Solid samples will be disposed 1 month and liquids 2 weeks after the date of issue of this test certificate Asbestos subsamples will be kept for 6 months
Approved By:	
Authorised Signatories:	Rob Brown Business Manager

Derwentside Environmental Testing Services Limited
Unit 2, Park Road Industrial Estate South, Consett, Co Durham, DH8 5PY
Tel: 01207 582333 • Fax 01207 582444 • email: info@dets.co.uk • www.dets.co.uk

Page 1 of 2

Summary of Chemical Analysis
Water Samples

Our Ref: 09-27202
Client Ref:
Contract Title: Royal Anne Galley

		Lab No.	189318	189319	189320	189321	189322
		Sample Ref	WS1	SS1	SS2	SS3	SS4
		Depth	0.10	0.10	0.10	0.10	0.10
		Other Ref					
		Sample Type					
Test	**Units**	**DETSxx**					
Arsenic Dissolved	ug/l	DETS 010	1				
Barium Dissolved	ug/l	DETS 042*	5				
Berylium Disolved	ug/l	DETS 042*	< 1				
Cadmium Dissolved	ug/l	DETS 042	< 2				
Chromium Dissolved	ug/l	DETS 042	< 5				
Copper Dissolved	ug/l	DETS 042	< 2				
Ferrous Iron	mg/l	DETS 085*		0.19	< 0.10	< 0.10	0.79
Lead Dissolved	ug/l	DETS 042	< 4				
Mercury Dissolved	ug/l	DETS 078	0.07				
Nickel Dissolved	ug/l	DETS 042	< 10				
Selenium Dissolved	ug/l	DETS 017	< 3				
Zinc Dissolved	ug/l	DETS 042	3				
Vanadium Dissolved	ug/l	DETS 042*	< 10				
Nitrite	mg/l	DETSC2001*		< 0.10	< 0.10	< 0.10	< 0.10
Nitrate	mg/l		< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Phosphate	mg/l		< 0.10	< 0.10	0.45	1.7	2.7
Boron	ug/l	DETS 020	4300				
Dissolved Oxygen	mg/l	DETS 031	9.4	0.8	0.2	0.7	0.4
Ammoniacal Nitrogen as N	mg/l	DETS 019		2.7	15	15	55
Sulphide	ug/l	DETS 024		830	1700	4400	16000
Sulphate as SO4	mg/l	DETS 076		2800	2400	2600	3200
pH		DETS 008	7.8	7.3	7.3	7.3	7.1

9 Appendix 2: SeaStar Survey Ltd S survey report

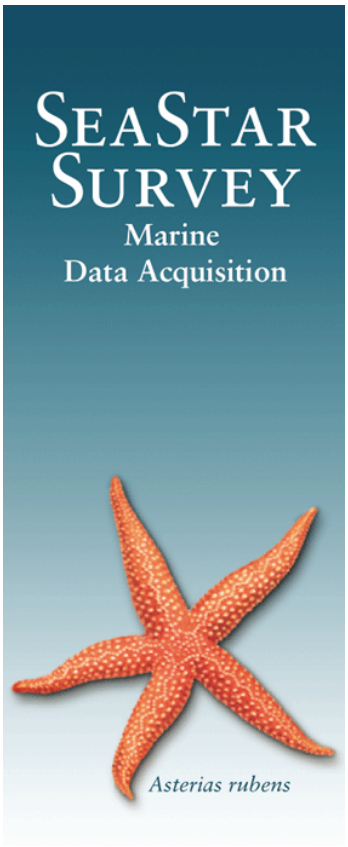
Cornwall County Council

Royal Anne Galley Bathymetry Survey

Survey Report – 2009

J/08/136

L.Plastow



SeaStar Survey Ltd, Ocean Quay Marina, Belvidere Road, Southampton, SO14 5QY

Tel/Fax: 023 8063 5000 e-mail: info@seastarsurvey.co.uk

9.1 Introduction

SeaStar Survey Ltd was contracted by Cornwall County Council to conduct a bathymetry survey of the Royal Anne Galley wreck and surrounding area on the 24th September 2009. The aim of the survey was to obtain bathymetric data in order to produce a contour map of the seabed depths around the Royal Anne Galley wreck.

9.2 Methodology

9.2.1 Survey area

The bathymetry survey was carried out using a Ceeducer digital hydrographic survey system, conducted from MV *Mytilis*. The mobilisation and de-mobilisation took place on the 24th September 2009.

The original survey plan comprised pre-defined survey lines within the 44,000m^2 survey area, consisting of a 50m x 50m area around the guns (survey line separation of approximately 2m) and a larger area surrounding the guns extending as far as the quadrant site, with a proposed line separation of 5m. Having previously worked at the site for the dive phase of the survey, it was apparent that this proposal was not achievable due to the underlying rocks. It was decided to use a number of positions to the south of the site as a start of survey line waypoint, and run the lines into shore on an approximate heading. Survey lines were spaced at approximately 5m. Eighteen main lines (heading SW-NE and NE-SW) and ten crosslines (heading W-E and E-W)) were conducted across the site. A further twelve lines were conducted over the area of the guns, with a survey line spacing of <5m. The vessel traversed the survey lines at approximately 2knots due to the swell and surge.

The Ceeducer was chosen for the survey due to the survey vessel not having a dry cabin. The Ceeducer is a waterproof self contained echosounder and navigational system with an integrated differential GPS receiver (Marine Beacon RTCM reception), electronics processor and data logger.

9.2.2 Horizontal control

The horizontal control for the survey was achieved by using a Hemisphere MD MGL-3 Differential GPS (DGPS), with the differential signal obtained from the Lizard. The DGPS obtained a satellite derived position in WGS84 latitude and longitude, which was recorded internally in the Ceeducer. A data transformation was performed within the survey software to convert the positions to UTM North Zone 30 (WGS84).

Due to the nature of the site, a navigation check was carried out by comparing the position on the Ceeducer with the position on the vessel GPS at the start and the end of the survey to check the accuracy of the DGPS signal.

9.2.3 Vertical Control

Echosounder

Vertical control for the survey was achieved by the use of the Ceeducer dual frequency (33 and 200 Khz) internal digital survey echosounder.

The echosounder transducer was mounted to the bottom of the vessels dive ladder at the rear of the port side to 1.39m below sea surface. The dive ladder was lashed with aft stays to reduce movement, ensuring the transducer head remained vertical and vibration in the transducer mount was kept to a minimum. The DGPS antenna was also mounted to the dive ladder directly above the transducer to remove the need for offsets and heading data.

The speed of sound through the water column was measured internally by using the temperature readings from the ceeducer temperature sensor combined with the internal

seawater setting (used for seawater in depths less than 20m) to calculate the appropriate speed of sound, which was then applied internally to the echosounder readings.

Tides

Tide corrections were achieved by applying tidal data obtained from the Channel Coastal Observatory tidal gauge at Newlyn.

The predicted tide data for Newlyn was converted to the survey site using tide height corrections based on actual observations at Newlyn. The predicted tide heights for Newlyn were subtracted from the actual tide height observations. This difference was then applied to the predicted tides at the Lizard Point.

The tide height data was applied to the echosounder results to reduce the recorded depths to Admiralty Chart Datum.

9.2.4 Survey processing and charting

Processing of the digital data was undertaken using the post processing tools within Hypack single beam editor software. The processing of the data involved the removal of spikes and other erroneous points from the data and the reduction of the depths using the corrected data acquired from the Channel Coastal Observatory tidal gauge at Newlyn.

9.3 Survey limitations

9.3.1 Weather conditions

The weather conditions throughout the survey were generally suitable to carry out survey operations.

Wind: west/northwest F 3-4

Sea State: moderate

Visibility: good

Weather: sun

Throughout the day the swell around the Lizard Point increased to 1-2m. In these conditions it was deemed unsafe for the vessel to continue due to the hazards of underlying rocks. It was deemed that sufficient data had been collected and as a result survey operations were ceased for the remainder of the day.

9.3.2 Obstructions

Across the site numerous underlying rocks are present, some of which are exposed on an ebb tide. As a result the vessel could not always transit on a set heading and had to alter course to avoid the rocks, and occasionally as a result, some lines were shorter than planned.

9.4 Equipment specification

Ceeducer Pro™

Echosounder dual frequency 33 and 200Khz

Six soundings per second

DGPS Position fixing every 2 seconds

Integrated differential receiver (Marine Beacon RTCM Reception)

Automatic echosounder velocity