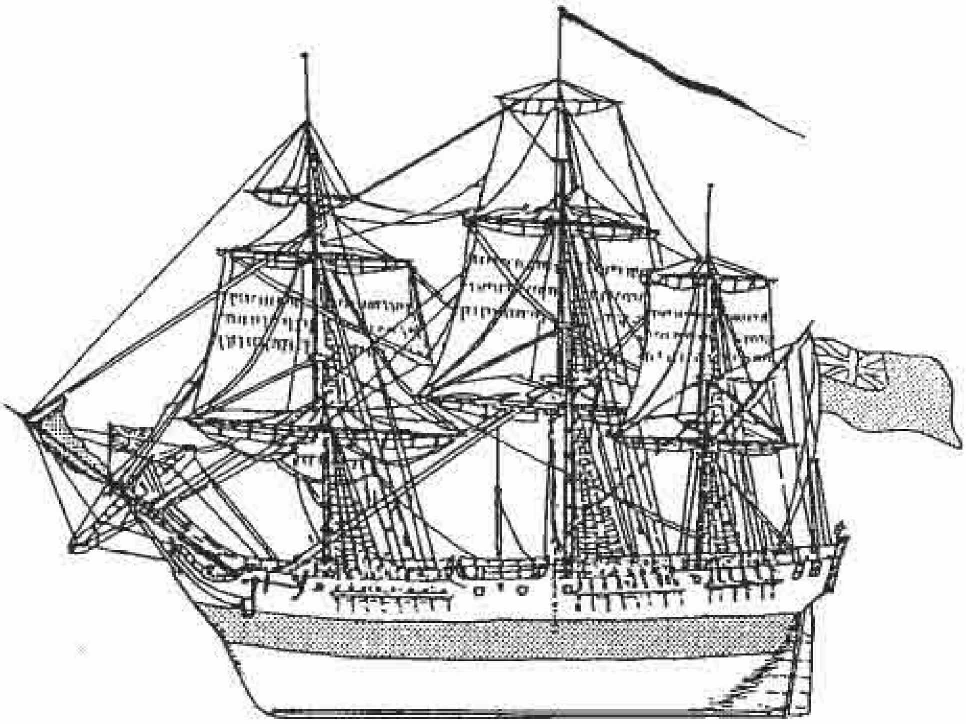
NORFOLK ISLAND GOVERNMENT PROJECT

1988 EXPEDITION REPORT ON THE WRECK OF HMS *SIRIUS* (1790)



COMPILED BY: GRAEME HENDERSON

with contributions by:

Ian MacLeod, George Cresswell, Bill Jeffery, Gaye Nayton, Isabel McBryde, Alan Watchman, Geoff Kimpton, Tom van Leeuwen.

Report - Department of Maritime Archaeology, Western Australian Museum, No. 37

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The Government of Norfolk Island coordinated the expedition. Mr Geoff Bennett, Minister for Commerce and Health, and Chairman of the Norfolk Island Bicentennial Committee applied himself with skilful dedication to ensure that the expedition proceeded and was such a success. Ms Gaye Evans, MLA, offered encouragement and introduced the team to many useful Island contacts. Mr Wayne Richards, ***Sirius*** Expedition Liaison Officer with the Norfolk Island Administration, organised much of the pre-expedition paperwork.

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Mr Bryan Busteed and Mr Tony Kennedy were among the local divers who assisted.

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Captain Tom Morton, Commander of the present day HMS ***Sirius*** , made available to the expedition two of his crew, Lieutenant Frank Mills and Petty Officer Bob Newton. Captain Morton also made his ship available for the launching of *The Sirius Past and Present.*

Ms Mary-Louise Williams, Senior Curator, National Maritime Museum, joined the expedition for several days as a goodwill ambassador.

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Dr Michael Borowitzka of the School of Biological and Environmental Sciences at Murdoch University identified the algae samples from the wreck.

The expedition team, consisting of Dr Ian Macleod, Ms Myra Stanbury, Mr Pat Baker, Mr Geoff Kimpton, Mr Terry Arnott, Mr Tom van Leeuwen, Dr Martin Sher, Dr Geoff Taylor, Mr Bill Jeffery, Ms Maree Edmiston, Dr George Cresswell and myself worked as a 'well oiled team'.

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Many others supported the work.

October 1989.

INTRODUCTION

This report describes the archaeological activities carried out in the field during October 1988 by an expedition, funded by British Airways, to conduct further investigations into the wreck of HMS ***Sirius*** at Norfolk Island. It also includes analyses carried out subsequent to the fieldwork and a review of the progress of the project since its inception.

Previous reports have assembled some background about the ship and the findings of a preliminary examination of the site (Henderson, 1984), and described the field activities of the February-March 1985 expedition (Henderson and Stanbury, 1985), and the January-February 1987 expedition (Henderson and Stanbury, 1987). Further information was published in the book, *The **Sirius** Past and Present* (Henderson and Stanbury, 1988).

Information in this report was collected by Dr Ian MacLeod, Dr George Cresswell, Bill Jeffery, Geoff Kimpton, Terry Arnott, Pat Baker, Tom van Leeuwen, Myra Stanbury and Graeme Henderson. Professor Isabel McBryde and Alan Watchman carried out the analysis and reported on the Aboriginal stone hatchet head found on the ***Sirius*** wreck site.

LOGISTICS

The expedition was run on similar lines to its predecessors: a group with maritime archaeological and associated skills was flown in from various parts of Australia for an excavation season lasting four weeks. The duration of the expedition was calculated to include at least some days of suitable sea conditions, given the cyclical nature of the high and low air-pressure bands passing over Norfolk Island.

The Norfolk Island Government organised personnel recruitment , transport and accommodation, work areas, the provision of a replacement inflatable dinghy and outboard, and the freighting in of necessary equipment. Accommodation was again arranged at Tavener's Farm. Two sedans were hired, and the Hon. Geoff Bennett loaned a Landcruiser.

A) Personnel

In selecting personnel the following three factors were given high priority. Firstly, there was the need to benefit from experience developed among personnel attending previous expeditions. Secondly, there was the need to obtain expertise from the oceanographic or coastal-geomorphological fields. Thirdly, there was the need for continued economy of numbers, bearing in mind the high cost of airfares and the availability of experienced divers on Norfolk Island. The result was an official team of thirteen, with several unofficial associates and a large group of Norfolk Island volunteers.

Name	Institution or Background	Responsibility
Graeme Henderson	Western Australian Museum	Expedition Leader
Myra Stanbury	Western Australian Museum	Registrar
Dr Ian MacLeod	Western Australian Museum	Conservator
Pat Baker	Western Australian Museum	Photographer
Geoff Kimpton	Western Australian Museum	Field Engineer
Bill Jeffery	S. Aust Dept of Environment	Surveyor
Terry Arnott	Maritime Arch. Assoc. of Vic	Equipment
Tom van Leeuwen	Maritime Arch. Assoc. of W.A	Divemaster
Dr Geoff Taylor(1st half)	Exmouth Hospital	Doctor
Dr Martin Sher(2nd half)	Cairns Private Practitioner	Doctor
Dr George Cresswell	CSIRO Tasmania	Oceanographer
Maree Edmiston	Artist	Artist
Sue Chenery(2nd half)	Aust Bicentennial Authority	Media Coordinator

Barley Christian, Mike Johnson, and Bevan Nicolai were assigned to the expedition by the Norfolk Island Government. As on previous expeditions, personnel worked as honoraries or were paid by their home institution.

B) Summary of Activities

1 October (Thursday)

Personnel arrived at Norfolk Island from Sydney at 1500 hrs. Henderson, Stanbury, Baker, Cresswell, Jeffery and Arnott), and from Auckland at 1600 hrs (MacLeod, Taylor, Kimpton and van Leeuwen). All were taken to the accommodation at Tavener's Farm.

2 October

A base was established in the boatshed at Kingston, and the inflatable dinghy was made operational. Jeffery and Arnott relocated survey benchmarks. Discussions were held with Curator Robert Varman and expedition organiser the Hon Geoff Bennett. The team familiarised themselves with the oxy-viva. Repairs were made on the inflateable dinghy. Edmiston arrived. The research design was distributed to team members.

3 October

Most of the team dived. Divers established buoys on the wreck site and commenced tagging and drawing ballast blocks. Some 20 were tagged. Henderson noted recent damage to the inshore anchor. This was reported to the Norfolk Island Government. Stanbury set up the computer and MacLeod examined material being conserved.

4 October

The wind had died, but the swell was up, so there was no diving. We continued setting up systems in preparation.

5 October

There was diving on site all day. Arnott found an anchor ring inshore. Most of the day was spent in removing sea urchins and seaweed from the site. Several divers suffered injuries from the spines.

6 October

The weather was good again. We were able to dive all through the day, aiming at removal of obscuring sea-urchins and weed growth. We became aware of more and more ballast blocks at the shoreward end of the site. Barley Christian agreed to make the pyramid for an underwater plaque. The pyramid will be of concrete, with 1metre sides, and weighing 1.04 tonnes. MacLeod lifted 1985 anchor from tank for inspection. It was found to be in excellent condition. Titration samples were taken. Cresswell and Duncan Edward made timber tide floats for plotting current flow data.

7 October

Diving finished early because in the rough conditions divers were accidentally knocking tags off ballast pigs. Kimpton joined Franklin to commence the construction of a carriage for the carronade currently being conserved on the Island.

8 October

There was no diving on the wreck site. Divers installed a tide guage, the current flow meter being at 13 metres. Stanbury worked on the previous season's collection. Bevan Nicolai painted a temporary coating on the 1985 anchor. A display of ***Sirius*** material will be prepared by team members for the Royal Norfolk Island Show. The remainder of the equipment arrived, including the computer and the current meter, which records speed, direction, salinity, temperature and depth.

9 October

The swell was still up, so there was no diving. We had plenty of other things to go on with however, including the development of a management plan for the ***Sirius*** , artifact conservation and management, etc. Baker developed film. Jeffery worked on the survey map. Edmiston drew artifacts.

10 October

We dived in the morning, and later in the afternoon as the tide began to rise. Measurements were taken on the anchors, and trilateration continued on the ballast. About 55 tags have now been attached to ballast blocks. Work continued on the management plan, but electrical surges wiped out several hours of work. Beef Buffett and Barley worked on construction of the concrete plinth for the underwater plaque. Team members observed with concern the many craters worn in the iron ballast blocks by the sea urchins.

11 October
The wind had swung round to the South West and blew very strongly. No diving could take place. Further measurements were necessary before work could start on the excavation of the ballast transect. Kimpton and Frank Randall completed roughing out the anchor stock for the anchor raised by the ***Sirius*** Expedition. Kimpton constructed 2-metre square grids to be placed over sections of the ballast mound for more detailed sketching. MacLeod addressed a meeting of the Norfolk Island Lions Club.

12 October
No diving was possible on the site. During the afternoon the inflateable was punctured badly on iron bolts protruding from the pier, so gluing repairs were attempted. A replacement boat (smaller, at 4 metres, with WA Museum outboard) was borrowed from National Parks and Wildlife.

13 October
The swell was still up so no diving on the site was possible. In the evening Cresswell addressed a meeting of the Norfolk Island Rotary Club.

14 October
The site conditions were the best we have seen. We started diving at 0745 hrs and continued until 1400 hrs when the tide had gone down to the extent of making work impossible. We took out the 2-metre grids, and MacLeod obtained his pH and potential measurements. Jeffery sketched ballast blocks. Others measured anchor rings.

15 October
The swell was up again, so there was no diving on site. Manufactured anchor rings were attached to the two previously raised anchors.

16 October
Site conditions were good through the rising tide. Divers continued drawing blocks under grids. Arnott found a coin (a two-maravedi dated 1774 and bearing the head of Charles III of Spain).

17 October
The biggest seas yet on this, and previous, expeditions, were seen on the wreck site. In the evening Henderson and Stanbury attended a dinner for the Duke and Duchess of Norfolk and Catholic Cardinal Sir James Freedman at the residence of Administrator Commodore John Matthew.

18 October
Unsuitable conditions again precluded diving on the ballast area of the site. The 1-tonne concrete plinth was placed on site, a difficult operation in the conditions. Bob Newton (present-day HMS ***Sirius*** diver) was involved in the operation. Arnott and Kerry Coop made steel plates for use with the hydraulic jacks on the ballast pigs. In the evening MacLeod advised a gathering of residents on the appropriate care of relics.

19 October
No diving was possible. MacLeod coated the anchor in preparation for its loan to the National Maritime Museum. Kimpton fitted the stock. More T-shirts were printed, the sales going well. In the evening all members attended a Presentation Dinner honouring the Duke of Norfolk, and Henderson gave an illustrated address.

20 October

The surf was very high on the site and no diving took place. The Norfolk Island Government has decided to loan to the National Maritime Museum of Australia the anchor raised, conserved, and fitted with a stock by the ***Sirius*** Expedition. A handover ceremony (to Dr Alan Bartholomaez, of the museum's Council) took place during the morning and the anchor was then loaded onto a Hercules for transport. There was also a plaque unveiling ceremony on the foreshore adjacent to the wreck.. After the ceremony the Duke and Duchess of Norfolk visited our workshop and laboratory.

21 October

The wind was from the south, gusting to 42 knots in the morning and getting worse during the day. Rain accompanied the wind. The press group had been on the Island for several days, doing a number of interviews with expedition personnel. Channel 9 required filming in the water, but this was done at Emily Bay. MacLeod, Kimpton and Franklin fabricated a sacrificial anode for the carronade still on site.

22 October

The wind was coming from the south-east, but conditions were no better than the previous day. A meeting was held to review progress and plans for the following week. It had become clear that the time necessarily occupied in surveying newly located ballast now precluded achieving the aim of conducting a transect through the centre of the ballast mound. Instead, it was determined that a transect be attempted at the shoreward end of the mound, involving the removal of only a small number of blocks. Cresswell and Jeffery planned to measure a bottom profile with a pole on a good day.

23 October

The sea conditions suddenly turned good. The 1-tonne concrete plinth was found to have moved 8 to 10 metres across the seabed during the stormy weather of previous days. We worked for much of the day on site, chipping on a ballast pig at the shoreward end of the mound. We found numbers of cannon balls, of 6 and 18 pounds, blocking the way on the north side of the mound. However the balls came out in excellent shape. Jim Tavener's boat was used to relocate the concrete plinth. MacLeod attached his anode to the carronade. Voltage was reduced to 200 millivolts. This effectively means that treatment of the carronade begins on the seabed. This is the first time this has been done as part of a management strategy.

24 October

Diving conditions were again excellent. We dived from 0730 hrs until dark. The first pig of the season (pig 15) was raised. About 7 cannon balls were raised. In the evening Henderson addressed a meeting of the Norfolk Island Historical Society.

25 October

The seas were still quite good. Diving started before 0730 hrs but the low tide made diving difficult by 1130 hrs. Five cannon balls were raised. MacLeod commenced treating the cannon balls as a joint project with the school science teacher. Baker carried out stereo-photography of the ballast mound. The team made a presentation of the gun carriage and a pastel representation of the wreck site by Edmiston to the Norfolk Island Bicentennial Committee, in response to a gift by that Committee of plaques to team members.

Baker presented a public lecture at the South Pacific Hotel in the evening.

26 October

We dived and freed (and raised) the second pig, a square block bearing a broad arrow. Then we chipped free a square pig, which was brought aboard in conditions of heavy swell. Channel 7's Hinch programme filmed on site and interviewed team members. A graphitised block and a square block were carried out to sea for raising.

27 October

Diving conditions were good in the morning. We chipped ballast and Henderson used the metal detector to locate the concreted second fluke of the Macquarie Place anchor, and an iron knee. Divers cleared grids from the site in preparation for departure. In the evening Henderson addressed a meeting of the Norfolk Island Rotary Club.

28 October

Diving conditions were excellent all morning. We raised two ballast pigs. During the morning we shifted the display anchor from its exposed position, where it was suffering from the elements, inside the Prince Phillip Youth Centre. Mike Pearson's (of the Heritage Commission) comments on the ***Sirius*** Management Plan arrived in the afternoon, so revisions were commenced.

29 October

Site conditions were perhaps the best ever. Van Leeuwen and Sher took another pig ashore. The team cleared the shed and workroom, and packed the gear for departure.

30 October

The team departed for Australia.

RESEARCH DESIGN

Preceding fieldwork seasons and archival studies enabled the development of a more formal statement of the aims for the 1988 fieldwork season, in the form of three research designs. The aims of the 1988 fieldwork season were to generate data for the testing of propositions in these three research designs, and for the testing of a model of the wreck process developed by research student Gaye Nayton.

DESIGN NUMBER 1

The Research Problem

One of the central issues being debated by Australian historians in the years leading up to and since 1988 is the reasons for the establishment of a European settlement at Sydney Cove in 1788. On the one hand are those who maintain the traditional view, that it was a 'knee jerk' reaction in response to there being too many prisoners to fit into Britain's gaols following the war with America: the need to find a place to dump convicts. Recently other scholars have begun to find other reasons, and one (Frost, 1980) argues that it was a considered, well executed plan to maintain and develop a permanent and substantial presence in the East. There was the need to prevent any French or Dutch claim to Australia; to obtain a source of naval supplies for fleets in the East; and to create a port, self-sufficient in wartime, for fleet refits and as a base for attacks on French, Dutch and Spanish bases and shipping. Convicts were an accompaniment, not a cause for the establishment of the colony.

Temporary expedient advocates such as Crowley (1955), Clark (1962), and Shaw (1974), argue partly on the basis of unquestioning acceptance of the journal entries of one of the First Fleet naval officers, that the ships of the First Fleet (and in particular the principal warship, HMS ***Sirius***) were hurriedly and inadequately prepared. Furthermore, they point to the allegedly poor performances by these vessels during and after that voyage as being due to their inappropriate design for vessels voyaging to the South Seas, inferior construction, inadequate fitting out for the voyage, and lack of proper maintenance. Philip Gidley King, Second Lieutenant on HMS ***Sirius*** during the First Fleet voyage is the officer most frequently cited by historians on this matter. Soon after the voyage commenced he wrote in his journal:

> The construction of a Kings Ship not being deemed proper for this Service the **Berwick** Store Ship was pitched on by the Admiralty & her name changed to the **Sirius** , so called from the bright star in ye Southern constellation of the Great Dog. She had been purchased on the Stocks by Government in 1781 & was sent once to America as a Storeship during ye War & once after the peace to ye Wt Indies since which time she had lay'n in ordinary at Deptford, till named for this Service, when she was taken in to dock & as the Yard people said, thoroughly overhauled, however we have frequently had reason to think otherwise, in the course of our Voyage (King, in Fidlon and Ryan eds, 1980: 5).

Four and a half months out to sea King returned to the subject of the ***Sirius'*** origins. After a day of uncomfortable rolling seas he wrote:

> ...a discovery has also been made which tends to prove (if it is necessary) the extreem negligence of the Dock Yard Officers in not giving the **Sirius** the inspection they certainly ought to have done. It being found necessary to rip up the lead which lined one of the Scuttles, the Carpenter in doing it perceived a rotten piece of Wood, which was broke off from one of the Top Timbers, on inspection we found that not only the top Timbers were rotten, but also that many of the futtocks were in the same condition, which brought the following anecdote respecting the Ship to light. She was built in 178- [King's blank space] in the River & intended for an East country man [a term invariably interpreted by First Fleet historians as denoting an East Indiaman] but in

> loading she took fire & was burnt to her wales, Government being in want of a burthensome ship to send Stores abroad in, the Navy board purchased the bottom of this Ship, she was taken into dock & run up with the refuse of the Yard, I have already said she went two voyages as a Store Ship since when she has had no repair as the late Surveyor of the Navy & Builder of ye Yard at Deptford reported her fit for the Voyage to which she is destined. Such is the Ship in which is embarked an Officer, whose reputation as well as that of the Nations, is concerned in the present arduous undertaking.... (King, in Fidlon and Ryan eds, 1980: 19).

Alan Frost, champion of the alternative viewpoint about the reasons for Australia's colonisation, has suggested that a thorough investigation of the mounting and assembling of the First Fleet might dispel many of these negative beliefs:

> No one has yet described adequately the mounting of the First Fleet. The relevant documents in *Historical Records of New South Wales* are only a small portion of those extant... A comprehensive description of this mounting would bury the myths that the Pitt Administration were generally indolent in assembling the Fleet, that they equipped the colonising party poorly, and that these features reflect their common disregard of the convicts' welfare (Frost, 1980: 218).

Major questions arising from these arguments therefore are:

i) Was the ***Sirius*** an appropriate, reasonably equipped and maintained vessel for its role as protector and provider in the first phase of the British colonisation of Australia?

ii) If the ***Sirius*** was an inappropriate, poorly built, ill equipped and badly maintained vessel, did this contribute to her loss at Norfolk Island in 1790?

iii) What were the particular structural, design and maintenance qualities which made her an appropriate or inappropriate vessel for her role as principal warship of the First Fleet, and protector and provider to the infant colony?

iv) Did these specific features have any influence on the way in which the ship broke up following her stranding on the reef in Sydney Bay, Norfolk Island?

Hypothesis 1.

The ***Sirius*** was an appropriate vessel for its role in the British colonisation of Australia.

Conceptual Framework of the Research

My background is that of an historian with experience in maritime archaeology. I agree with those who argue that historical archaeology should deal with historical problems (questions whose answers provide insights about past events or processes), as well as archaeological problems (whose answers further the development of predictive patterns and/or laws). The problem here dealt with is an historical one, but that is not to say that I am not concerned with explanation. I have looked to the discipline of history for a model (a conceptual unit that organises a body of factual information into a more general framework) dealing with the beginning of the process of European colonisation of Australia. I have taken an explicit explanatory approach, and employed both historical and archaeological methodology to prove one element of the argument for a considered, well executed colonisation plan.

Previous Research

The ***Sirius*** Project was initiated in 1982 by staff from the Commonwealth department responsible for the administration of the *Historic Shipwrecks Act, 1976* (now the Department of the Arts, Sport, the Environment, Tourism and Territories) who were interested to know whether anything was left of the wreck of the ***Sirius*** on the reef at Norfolk Island when she had been lost in 1790. Site management issues were of high priority. The fieldwork, funded by the Australian Bicentennial Authority, was directed towards establishing where the ship struck, how it broke up, where the remains were distributed to, and the quality of preservation of those remains. The Project paid for volunteers (recruited from institutions and the general public) to be transported to and accommodated on Norfolk Island for the field seasons.

Research stages have consisted of observation (which included sampling), formulation of questions and formulation of hypotheses. An initial site reconnaissance in 1983 (5 days) was followed by an information search in archives, field survey in early 1985 (3 weeks) and early 1987 (3 weeks), and a more comprehensive information search and evaluative stage in late 1987-early 1988.

The work in 1985 and 1987 was essentially exploratory - an overview and assessment stage aimed at identification and definition of sites derived from the ***Sirius*** , since little was previously known of either the sites or the historical background of the ship. Site accessibility (constraints on observer mobility) was extremely limited by the high energy white-water surf conditions normally present, and despite the presence of a stable calcarenite seabed the visibility (extent to which an observer can detect the presence of archaeological material at or below a given place) was limited by seabed vegetation and marine creatures. Thus the ballast mound, thought to mark the principal deposit, was not located until midway through the 1987 season. Funding constraints precluded substantial information gathering (in archives in the UK) until after the 1987 fieldwork. Only after the principal deposit was located in 1987 was it possible to formulate important and relevant testable hypotheses about the site.

Methods

Archaeological investigations can, or have the potential to, prove or disprove hypotheses relating to the process of colonisation. When the foundations of the First Government House at Sydney were uncovered recently archaeologists commented that initial indications were that it was a substantial structure - a building designed to last, consistent with the view that, at least by the time that building was erected, there was a perception of a permanent colony rather than a temporary prison (Mulvaney, 1985). If further exploration of the Government House remains substantiates this argument then it will strengthen the case of the historians arguing for a permanent and substantial presence.

Analysis of the archaeological remains of ships from the First Fleet, if sufficient material has survived on the seabed, can also be expected to affect the interpretation of an aspect of that broad historical question. Analysis of other shipwrecks, where substantial wooden structure has remained on the seabed, has enabled comparisons to be made about the quality of construction of those vessels (Henderson, 1986:148-150). Inappropriate First Fleet vessels in poor condition would support the argument for a limited British plan.

Most of the First Fleet has vanished. However one example, the ***Sirius*** , is available for both historical and archaeological study. Proving that the ***Sirius*** had been an appropriate vessel will go some considerable way towards destroying the argument that the First Fleet was a hasty and shabby effort directed towards a temporary expedient - getting rid of convicts from hulks. Negative evidence, of an inapproriate vessel, will damage the Frost thesis. This is not to say that the condition of the ***Sirius*** was the only element in the organisation of the First Fleet - far from it. For a start, the ***Sirius*** was only one of 11 vessels in the First Fleet. However, it is a good example, because both contemporary observers and modern historians have cited ***Sirius*** as **the** prime deficiency in the First Fleet. Thus if it can be proved that the ***Sirius*** was appropriate it is an inference that the whole of the First Fleet was likewise.

It is necessary at this stage to explain my use of the term 'appropriate', in the hypotheses, in the context of Frost's model of a considered, well executed colonisation plan. What would be an 'appropriate' vessel in terms of: a) the role to be played in the colonisation process as outlined by Frost? and b) the standards of the time? For the vessel to be considered appropriate these factors need to be compatible with the following stages in the life of the vessel: design; construction; maintenance during early years; refit for the First Fleet voyage, including outfitting; and maintenance during and after the First Fleet voyage.

Was the ***Sirius*** appropriate in terms of the role she was to play? During the First Fleet voyage itself the ***Sirius*** was required to perform three roles: as protector, co-ordinator and supply vessel. It was necessary that the Fleet be protected with guns, but against whom? Who would attack a fleet of convicts ***en route*** to Australia? The French, Dutch and Spanish were rivals, but they were not engaged in open war with Britain in 1788. The threat from privateers, pirates or other nations was not of a high level at that time in the waters to be traversed. There was the question of a threat from within, from the convicts. Had the First Fleet set out several years later, the ***Bounty*** mutiny might also have heightened awareness of potential threat from naval personnel themselves. In its role as co-ordinator (the expedition commander was on board until after leaving South Africa) it was required that the vessel be of sufficient size to be comfortable and suitably impressive. In addition the vessel needed sufficient speed and manoeuvrability both to keep up with the convoy and help in keeping the convoy together by rounding up stragglers etc. As a carrier of substantial supplies she would share the load with other First Fleet vessels, and to perform this role it was necessary that she be roomy and watertight. She was also required to act as a troop transport, providing room for marines, to protect and control the convicts at sea and at Sydney.

After arrival at Sydney the ***Sirius*** was required to perform four roles: as protector, supply vessel, exploration and communication vessel. As protector she was required to stave off any attack upon the settlement from other European powers, convicts or Aborigines, and attacks upon herself from any hostile vessels in Australian waters or elsewhere in the region. With the departure of the convict ships she would, being relatively large and roomy, be the only suitable ship for obtaining supplies if necessary from overseas, and for communication with the outside world. As an exploration vessel she was required, in conjunction with the smaller ***Supply*** (selected to carry out the inshore work), to inquire into the various localities of suitable naval supplies and assist in establishing means of exploiting these resources. Coastal exploration would give the British knowledge of potential other-nation bases etc, necessary from the strategic viewpoint.

It is necessary also to examine the term 'appropriate' against the standards of the times as they relate to ships. Vessels sailing to the East were generally of a larger size (there were exceptions), between 300 to 600 tons, the East Indiamen being larger than this. They were armed to some extent. Their hulls were, by the 1780s, frequently sheathed with copper, to reduce the effect of teredo worm and weed growth. The construction was of heavy timber, for the rigors of the rounding of the Cape of Good Hope and the rough seas beyond. And they were generally not particularly old, because timbers and fastenings were known to deteriorate. Not fully appreciated at the time was the exact nature of the effect of copper sheathing on iron fastenings - by electrolysis it caused corrosion of the iron bolts holding a ship's frame together.

What then, given the role expected of the ***Sirius*** , and the standards of the times, would be the elements of an appropriate or inappropriate vessel? The design would not be that of an East Indiaman. Such a vessel would be entirely inappropriate, being too slow for the roles of co-ordinator and protector of the First Fleet, too large for the roles of explorer and communicator in the South Seas, and too heavily crewed for the colony to comfortably support. A purpose-built warship would also be inappropriate, in the roles of supply ship and exploration vessel. Most appropriate would be colliers or Baltic traders (weatherly ships built for room, strength and the ability to take the ground), or naval storeships or transports (designed to sail in convoy and carry cargo and men). For his great 1760s and 1770s South Seas voyages James Cook used the **collier-built** ships ***Endeavour*** (369 tons), ***Discovery*** (298 tons), ***Adventure*** (330 tons) and ***Resolution*** (460 tons). For his breadfruit collecting at Tahiti in 1788 William Bligh used the **naval transport** ***Bounty*** (220 tons). Jean Francois de La Perouse set out on his voyage of Pacific discovery in 1785 in the two **naval storeships** ***Boussole*** and ***Astrolabe*** of between 450 and 500 tons.

In discussing the appropriate size for the vessel it is necessary to look beyond its role as principal warship of the First Fleet. George Teer, the Agent for Transports at Deptford, was of the opinion that a 44-gun ship (800 to 900 tons) was the ideal (Knight, 1988:18). Colonisation scheme advocates James Matra and Sir George Young both thought that a 40-gun ship would be suitable. Young said:

> I should require a Ship of War; say the Old ***Rainbow*** , now at Woolwich, formerly a Ship of 40 guns, as the best Constructed for that purpose of any in the Navy; with only half her lower Deck Guns, and 250 Men, One Hundred of which should be Marines, a Store Ship likewise of about 600 Tons Burthen with 40 Seamen and 10 Marines, and a small Vessel of about 100 Tons, of the

> Brig or Schooner kind with 20 Men, both fitted as Ships of War, and commanded by Proper Officers (Frost, 1980:27).

James Cook, the most experienced of the South Seas navigators, doubtless would have disagreed with these shore-based men. The qualities he required:

> are not to be found in ships of war of 40 guns, nor in frigates nor in the large three-decked West India ships, nor indeed in any other but North Country built ships such as are built for the coal trade...

Fifth raters were popular convoy leaders in the Atlantic. However, there was no need for such a heavy arsenal on a ship at Sydney at that time. A 40-gun ship (or a 44-) would be too large for the exploration work envisaged, and large ships such as this would have placed a heavy maintenance burden on the isolated infant colony. A vessel of 400 to 600 tons (with a tender for inshore work) would be large enough. Other ships of such tonnage were used in the South Seas in the 1780s and around Australia in later years. HMS ***Pandora*** , sent out to apprehend the ***Bounty*** mutineers in 1789, was 513 tons. HMS ***Success*** , which transferred a trading post in the north of Australia to a more favourable position in 1827 was 504 tons. HMS ***Challenger*** , which with the bomb ***Sulphur*** hosted the first fleet to Swan River in 1829, was 603 tons.

Construction-wise the most appropriate vessel for a voyage to the South Seas up to August 1786 would have been built of oak, fastened with iron or copper, sheathed with copper, and heavily built. The general order to ensure that all naval ships had copper bolts was issued in August 1786.

The sailing performance criteria appropriate for the First Fleet consort were not stringent, but the role subsequent to arrival was at times more demanding. To sail in convoy required that she be able to average some 3 1/2 knots, and to reach higher speeds with the rest of the fleet. Given a conservative route plan there were no heavy requirements for steering or weatherliness, but the consort needed to be able to sail satisfactorily under load.

Some general requirements were laid down by the navy as to the appropriate frequency and nature of refits for particular types of vessels. In the 1780s a refit was required every three years, and consisted of the stripping of rigging, guns and stores, then docking, breaming and graving before preparation for sea.

Maintenance during long voyages was a source of contention between dockyard and shipboard personnel. However, once a ship had left port it was appropriate that the crew carry out all necessary maintenance to ensure the vessel's security until the next refit. This included general internal carpentry, attention to fittings, and caulking.

We now have a model of the appropriate vessel for the role envisaged by Alan Frost, and need to examine whether the ***Sirius*** fits into its parameters.

A. The Historical Resource

Given the paucity of secondary historical sources reading was directed to primary sources to answer the following questions:

Q1. What was the design of the ***Sirius*** ?

A1. Archival data has now shown that the ***Berwick*** was not designed as an East Indiaman (as contended by modern historians), but that she was designed for the Baltic trade, and was thus not dissimilar to the highly applauded vessels used by Cook, or the vessels used by Bligh and La Perouse in their South Seas voyages of exploration, scientific discovery and commerce (Henderson and Stanbury, 1988). The ***Berwick*** was started as a Baltic trader, (a vessel type requiring many of the same features as the North-Country-built colliers) and finished as a naval storeship. Then she was commissioned as a 6th Rate warship, but not outfitted strictly in accordance with this rating. Thus the vessel which sailed in the First Fleet had elements of Baltic trader, naval storeship and warship, a suitable combination for its South Seas roles of explorer, troop and supply carrier, and protector.

Q2. What were the vessel's size, construction materials and fastenings, and was she sheathed with copper?

A2. The ***Sirius*** was of 511 tons at the time of construction, fastened with iron bolts, and sheathed with copper, an appropriate model for the early 1780s. The type of timber used in her construction is not known.

Q3. Was the vessel burned to the water-line on completion and then rebuilt with the refuse of the dockyard?

A3. No evidence has been found to support the contention (based on King's anecdote), that the vessel was burned to the water-line, and the ample dockyard records indicate that she was well-built prior to Navy purchase, and completed according to normal dockyard practice.

Q4. Was the ***Sirius'*** sailing performance reasonable prior to, during, and after the First Fleet voyage?

A4. The accounts given by the ***Sirius'*** commanders, Lieutenant Prideaux, Captain Phillip and Captain Hunter, all indicate a good performer. These are the men who knew the vessel's capabilities best. Prideaux's account is the only comprehensive assessment of her sailing qualities. He gave a picture of a vessel which had a good turn of speed, steered well, handled heavy gales and light seas, and was favourable in head seas. Hunter thought 'she was exceedingly well calculated for such a service' and 'a very... convenient vessel.' Joseph Nagle, one of the crew, recalled that when the ***Sirius*** got underway at the Mother Bank, 'Our ship being so deep loaded with stores, and having large buttocks, we could scarcely steer her until we got better acquainted with her' (Nagle, quoted in Knight, 1988). The ***Sirius*** must have handled well for the rest of the First Fleet voyage, judging from the journals. At sea the ***Sirius*** performed better than most in the Fleet, and the First Fleet clearly performed well in comparison with other convoys of the period. The ***Sirius*** had difficulty weathering a part of the Tasmanian coast during a storm in 1789, but that was due to Hunter making an error in her navigation, and there was no reflection upon the vessel's performance by the crew (see Bach, 1968:406). Bach, in his comprehensively edited verson of Hunter's journal, writes of this incident that:

'Experience... evinced that she was altogether adequate to the service for which she was destined; and carried her crew through one of the most tremendous gales, on a lee shore, that the oldest seaman remembered'.

The suggestion has however been made by some modern historians that ***Sirius*** was not manoeuvrable, and that this was demonstrated by her shipwreck.

Q5. Was the ***Sirius*** poorly refitted for her commissioning in 1787?

A5. In some respects the dockyard and shipboard journal evidence points to faults in the refit.

a) Copper bolts were driven in addition to the existing iron bolts. All of the ***Supply'*** s iron bolts were replaced, and had this been done on the ***Sirius*** there would not have been the possibility of a corroded iron bolt dropping out while at sea and producing a leak in 1789. Phillip and Hunter were aware of this possibility, and carried a quantity of spare copper bolts on ***Sirius*** during the voyage.

b) Caulking was claimed to have been inadequate on the topsides. However this was a minor issue, which could be attended to by the crew.

c) Rotten timber was discovered during the voyage. This perhaps developed during the earlier layup period, but did not seriously impede the *Sirius'* performance. The methods normally employed in checking for rot prior to the nineteenth century could not be expected to locate all rot. Until 1808 surveys were generally superficial.

d) The copper sheathing was not entirely renewed.

Q6. Was the *Sirius* poorly maintained during her time in the South Seas?

A6. This question is not adequately answered in the documentary record.

Thus while questions 1, 2 and 3 have been answered in ways indicating an appropriate vessel, questions 4, 5 and 6 still require resolution. These questions can be addressed archaeologically if:

a) sufficient structural remains have survived on the *Sirius* site, and
b) the means are available to appropriately analyse the material.
c) the environment of the vessel's loss can be effectively analysed.

B. The Archaeological Resource

When the *Sirius* struck the reef her iron ballast, like that of any ship, lay on both sides of the keelson. The historical record shows that the *Sirius* remained upright, at least during the first week after it struck, and there is no reference to the vessel being overturned.

Hypothesis 1A

The *Sirius'* ballast was secured (that is, chained together as a matrix) over part of the ship's bottom. This can be tested by physical observation of ballast blocks in a protected position on the seabed. The presence of chain can be regarded as a positive test result, while an absence of chain can be taken as a negative test result. Corrosion may be expected to have removed all trace of iron chain from exposed blocks.

Hypothesis 1B

The matrix was partially maintained during and after the process of destruction of the *Sirius'* upper works. Again, this can be tested by physical observation of the ballast blocks on the seabed.

Hypothesis 1C

The matrix was sufficient to allow preservation of elements of the ship's bottom. In the case of the ***Batavia*** of 1629, blocks of stone formed a matrix over a section of ship's timbers, and despite the site lying on a turbulent, shallow shelving reef, these timbers were preserved. This hypothesis is tested by:

a) survey of the ballast mound to establish orientation.
b) excavation of a transect - that is, removal of the ballast blocks, through an area of density, to reveal any surviving timber or copper structural elements.

Hypothesis 1D

Examination of elements of the surviving ship's bottom will provide data relating to the nature of the construction and maintenance of the *Sirius'* hull, indicating a well constructed and reasonably maintained ship. This is tested by:

a) Recording of all details, and observing whether fastenings are of iron, copper, or a combination, and whether the hull is sheathed.
b) Sampling elements of the ship's bottom structure.
c) Metallurgical analysis of metals to indicate where made, materials, strength, when made, signs of wear and tear, and indications of when put into use.
The presence of copper will be regarded as positive evidence, iron as negative. If copper is present, tests will be made for whether it is all of the same nature,

that is, in terms of chemical composition, corrosion and wear, to establish whether some was replaced at Sydney.

d) Testing of wood samples for wood type.

Hypothesis 1E

Examination of other fittings from the wreck will also provide data indicating the vessel's condition to have been reasonable. Gaye Nayton's model will be used to select sampling locations. Material previously raised will also be analysed, including:

a) Anchors, to establish size, number and condition. Do they match specifications for a 20-24-gun ship?
b) Cannon, to establish condition?
c) Pumps, to establish type. Are they of outmoded design, or a new one on trial?
d) Rudder fittings, to establish age, condition.
e) Other structural materials.

If these hypotheses are answered in the affirmative, then it will be a strong argument in favour of the ***Sirius*** having been an appropriately selected vessel in reasonable condition. This in turn supports Frost's model of a permanent and substantial British presence.

DESIGN NUMBER 2.

The Research Problem

A good deal of effort has been spent by archaeologists on the ***Sirius*** site trying to establish its condition. The problem is common to most sites investigated in Australian waters - that archaeologists have had to disturb sites in order to evaluate their condition and extent. However it is particularly difficult on such an inaccessible site as the ***Sirius*** to assess condition. If it were possible to establish a degree of correlation between biophysical environment and the condition of the sites of ships lost in that environment then one could predict a site's condition (and thus its potential to answer specific questions), either without any prior site disturbance, or with reduced prior site disturbance. Some attempts have been made in Europe to explore the possibility of such a correlation. The question which arises then is: Can European models (or adaptations of those models) of correlation between biophysical environment and wreck site condition be usefully applied to Australian sites in a predictive sense?

Hypothesis 2.

A degree of correlation can be established between the biophysical environment in which a ship is wrecked, and the condition of the shipwreck remains on the seabed, for Australian waters.

Conceptual Framework of the Research

By extending the implications of uniformitarian theory (attributing geological processes and phenomena to forces acting continuously and uniformly) to the wider set of elements considered by oceanographers and coastal geomorphologists it should be possible to measure the degree of correlation between the most relevant environmental attributes and the quality of the archaeological remains on any shipwreck site.

Previous Research

A study carried out on 20 sites in British waters (Muckelroy, 1978), examined the following variables:

1. Maximum offshore fetch, within 30° of the perpendicular to the coast.

2. Sea horizon from the site; i.e. sector within which there is more than 10 kilometres of open water.

3. Percentage of hours during which there are winds of Force 7 or more from directions within the sea horizon.

4. Maximum speed of tidal streams across site.

5. Minimum depth of site.

6. Maximum depth of site.

7. Depth of principal deposit on site.

8. Average slope of the seabed over the whole site.

9. Underwater topography: the proportion of the site over which the seabed consists of geologically recent sedimentary deposits.

10. Nature of the coarsest material within these deposits.

11. Nature of the finest material within them. In ordering sites on this attribute and the previous one they were ranked initially according to broad categories of material, and then according to the relative importance of these deposits on the different sites.

The attributes were ranked across the 20 sites and the relationships quantified. The sites were grouped into five classes according to condition, and this condition was correlated with the six most relevant environmental attributes (9,10,11, 8,2 and 1). Muckelroy (1978: 165) recognised the limitations of his sample numerically and geographically, and argued:

> Similar detailed studies are required for many different parts of the world before any factors common to them all can be isolated.

In another recent study, on Quaternary coastlines and submerged prehistoric sites oceanographers Masters and Flemming (1983) saw the following factors as favouring the preservation of cultural material:

1. A sheltered low energy environment, protected from waves and currents, for example, within an estuary or sheltered bay, in the lee of islands or headlands, within a karstic cave, or at the head of a submarine canyon.

2. Environments which, although exposed to high energy (waves or currents) are protected by adequate sediment cover (for example equilibrium beaches, marshes, wind blown sand).

3. A sequence of events which first buries the site in sediment, and then exhumes it gradually, for example, covering by terrestrial sediment, followed by submergence, followed by slight wave or current action.

The chemists at the Western Australian Museum's Department of Materials Conservation look at these environmental parameters from a different perspective. The site temperature is of major importance, largely determining the rate of deterioration of both metal and non metallic objects. Associated with the temperature is the level of dissolved oxygen on the site, that is, whether it is fully aerated, partly aerated, or anaerobic. Levels of oxygen determine the corrosion mechanisms and modes of decay. The level of pollution, from, for example, sulphides, is related to these factors. Salinity (dissolved chlorides being of major importance) affects glass and ceramics as well as metals. The pH level (acidity) affects microenvironments under concretions. Marine organisms form protective concretions. The distribution of artefacts influences the affect of their electric fields, iron for example giving cathodic protection to silver, copper and brass.

Methods

Biophysical environment and site condition can be correlated according to Muckelroy's attributes. This can be tested by recording the relevant environmental attributes and assigning a class, examining the condition of the site and noting the class, and seeing whether they match. If they do match, then Muckelroy's model is valid for this site. An oceanographer (Dr George Cresswell)) will co-ordinate the collection of the data.

Hypothesis 2B

Other Australian sites will show a correlation according to Muckelroy's model. This can be tested on Western Australian sites as on the *Sirius* site.

If these hypothesis are proved negatively, other environmental attributes will be tested.

DESIGN NUMBER 3

The Research Problem

Some historians have seized upon the ***Sirius'*** loss at Norfolk Island as evidence of poor sailing performance. ***Sirius*** and the tender ***Supply*** carried convicts and stores to the island in March 1790, but encountered heavy weather from the south west.

On the 19th the gale moderated, and a wind from the south-east brought the ***Sirius*** close to Phillip Island. Captain Hunter saw the ***Supply*** lying to the wind in Sydney Bay, and the signal flag on shore which indicated that long-boats could land without danger from the surf. Hunter stood in for Sydney Bay, came close to the south point of Nepean Island, and soon after 10 am brought the ship's head to the wind, facing out to sea. The boats were put down and loaded with provisions. Lieutenant Ball of the ***Supply*** called out and waved his hat towards a reef off the west point of Sydney Bay, warning that the two vessels were drifting perilously close to it. Both vessels set sail to windward on a port tack. The ***Supply*** was ahead, but to leeward of the ***Sirius*** . At that time unfortunately the wind shifted two points (22°30') to the southward, making it impossible for the ship to weather the rocks off Point Ross on their port tack.

The ***Supply*** changed to a starboard tack and passed just clear under the ***Sirius'*** weather bow. Hunter tried to do likewise, but the ***Sirius*** missed stays and fell off the wind, heading again towards the rocks off Point Ross. Now Hunter's only option was to wear ship (to change to starboard tack by turning the ship's head away from the wind) and endeavour to sail eastward past the landing point and between the east point of Sydney Bay and Nepean Island. But the combined forces of the onshore wind and the current made it clear, as they passed the landing, that the vessel would not weather the reef. Hunter desperately tried to change tack:

> The helm was again put down, and she had now some additional after sail, which I had no doubt would ensure her coming about. She came up almost head to wind, and then hung some time, but by her sails being all aback, had fresh stern way: the anchor was therefore cut away, and all the haulyards, sheets and tacks let go, but before the cable could be brought to check her, she struck upon a reef of coral rocks which lies parallel to the shore, and in a few strokes was bulged.

In other words, because the ***Sirius*** failed to change tack, the wind blew her backwards on to the reef, and the vessel was holed.

The question which arises then is:
Did inappropriate design or poor condition contribute to her loss at Norfolk Island in 1790?

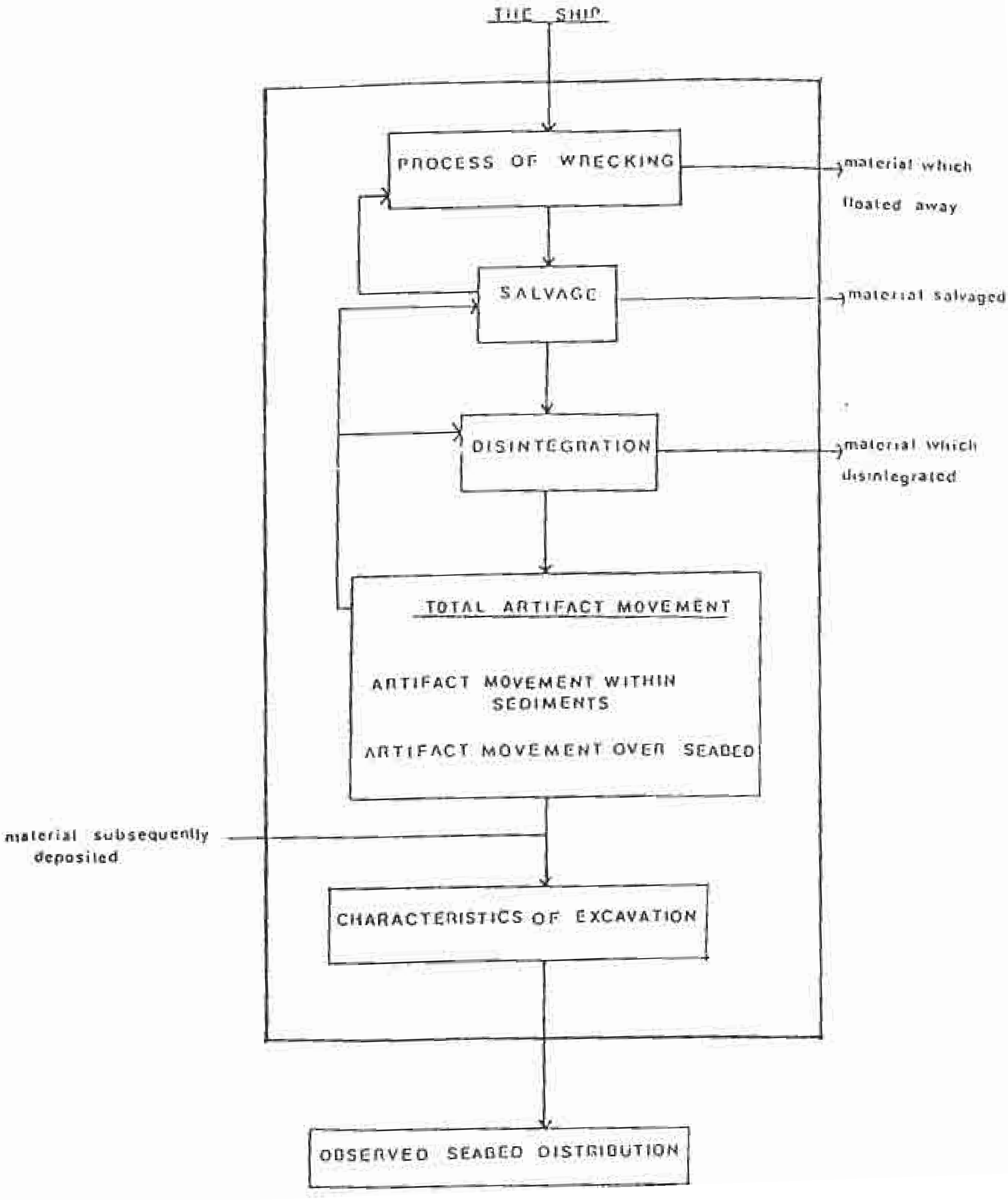
Hypothesis 3.

The loss of the *Sirius* at Norfolk Island was not attributable to its being an inappropriate vessel or to its condition.

Method

Data will be collected by an oceanographer at Norfolk Island to assess the rate of drift on the day the ***Sirius*** commenced offloading. This data will be used to estimate the vessel's position when sail was made. That in turn will be used to estimate ***Sirius'*** course *vis a vis* the wind

MODIFIED FLOW DIAGRAM OF A SHIPWRECK. Gaye Nayton



direction when she missed stays off Point Ross, and her course *vis a vis* the wind direction when she failed to go about off the landing. That data can then be judged against other information relating to reasonable levels of performance for three-masted ships of the 1790s. The other information will include eighteenth century records, comparison with the sailing abilities of a modern three-masted sailing ship (the ***Leeuwin***), and comparison with the sailing abilities of a modern replica of an 18th century vessel (***Endeavour***).

The Nayton Model of the *Sirius* Shipwreck

Archaeology student Gaye Nayton submitted, as part of the requirements for the Degree of Bachelor of Science (Honours) a dissertation entitled 'The Wreck of the ***Sirius*** : Testing an Archaeological Model of a Shipwreck.' The work comprised a test of the Muckelroy (1979) model of a shipwreck system. Each factorial component of Muckelroy's model was applied to the data generated by archaeological investigation of the ***Sirius*** wreck site. Nayton found that a direct correspondence between the archaeology and model was not established. Additional factors were proposed and a modified version of the general processes involved in wrecking posited.

Nayton's model (see diagram) integrates historical data and site formation processes to explain the pattern of artifacts recovered from the seabed. The model documents ship movement and damage across the site, and thus offers an explanation for the spatial arrangement of heavy artifacts across the reef. The archaeology of small artifacts is seen as reinforcing this picture and agreeing with historical documentation of damage to the ship.

The model is mainly of the process of wrecking, and Nayton sees the site as offering less potential to answer questions about the ship itself, because of the heavy salvaging the vessel was subjected to. But Nayton believes that further excavation, particalarly if the site of the final resting position is recognised and excavated, may help to partly redress that situation.

METHODOLOGY ON SITE

The spirit of research designs 1 and 2 were incorporated into the Minister's permit for the expedition to carry out work on the site (design 3 involved measurements off the site). The permit imposed the following conditions:

- i) Any historic relics recovered from the wreck site will remain in the custody of the Government of Norfolk Island, except where an alternative arrangement is necessary for conservation reasons;
- ii) All archaeological work will be at the direction of Mr Graeme Henderson, Expedition leader;
- iii) Within reason the work programme set out in schedule 2 shall be adhered to;
- iv) Following preparation of the site plan the location of the transect will be selected to provide for the maximum long term environmental stability of the site and to limit the trench size to the minimum necessary to achieve the research aims;
- v) No part of the site shall be damaged unnecessarily and no artifact shall be left exposed on the site at the completion of the planned programme of excavation;
- vi) The maximum trench size under this permit will be nine square metres of plan view;
- vii) All excavation work will be carried out under the supervision of Mr Graeme Henderson, Mr Bill Jeffery, Dr Ian MacLeod or Mr Pat Baker;
- viii) All material recovered will be conserved to standards outlined in the Australian Institute for the Conservation of Cultural Materials code of ethics;
- ix) This permit is effective from 1 October 1988 until 31 October 1988 (inclusive);
- x) A detailed report of the expedition, to include detail of the work carried out, condition of site, any artifacts recovered, conservation program for recovered artifacts, recommendations concerning site security and any other detail considered relevant, will be provided to the Department of the Arts, Sport, the Environment, Tourism and Territories by October 1989;
- xi) My Department shall be advised of any arrangements made pursuant to this notice.

A) Work Programmes

The work programmes (schedule 2) were outlined in the permit as follows;

Work Programme 1 - on questions relating to fitting out and maintenance of HMS *Sirius* .

1. Remove weed growth in vicinity of ballast pigs.
2. Attach number tags to ballast blocks.
3. Count and sketch the distribution of the ballast blocks.
4. Trilaterate the ballast pigs and then draw a plan of the ballast mound.
5. Determine the position of the transect.
6. Mark the transect with a stainless steel wire.
7. Draw the transect position on the ballast plan.
8. Within the transect chip free and raise pigs from the reef hard pan; collecting any free floating artifacts.
9. If items of hull structure are found underneath then work stops until that structure is recorded and recovered.
10. Items of hull structure will be examined by the archaeologist in charge in relation to expedition objectives as outlined in the research design.
11. If holes are found in the reef pan under the pigs then work stops until assessed. Holes large enough to affect current flows will be backfilled with basalt stones taken from Norfolk Island.
12. All artifacts freed during the process of freeing ballast pigs will be raised, catalogued and preserved.
13. The remaining two anchors will be accurately measured.
14. Raise the loose anchor palm for comparison with the anchor in Macquarie Place, Sydney.
15. The site will be visually examined for items of structure or fitting out.

HMS SIRIUS (1780-1790)
WRECKSITE PLAN
NORFOLK ISLAND
flat reef
SCALE
METRES

Work Programme 2 - on testing the Nayton model of wreck processes.

16. The Nayton model represents the process of wrecking. It will be tested by observation and metal detector survey. Any concentrations of material will be mapped and assessed. Material will be raised if exposed in the process of location and mapping

The work schedule was not completed during the 1988 field season, because divers found many more ballast pigs on the site than had been expected, and the surveying of this ballast left little time for any excavation work.

Weed growth was removed by cutting with a knife or by plucking with a gloved hand. During this process it became clear that the sea urchins in the vicinity of the ballast would also have to be removed, because they posed a danger to working divers and they obscured the form of wreck material from photographers, surveyors, conservators and excavators. The removal of weed and urchins continued throughout the season.

Number-tags were made from rectangular plastic sheets with a length of elasticised cord ('oki-straps') attached to each corner. A large fish hook was tied to each of the cord ends for purchase on the sides of the ballast pigs. Divers were cautioned not to hang from the 'oki-straps' during wave-buffetting because of the danger of hooks penetrating the body. About half of the known pigs were sufficiently exposed to be fitted with a number-tag. This system was adequate for normal sea conditions but a storm midway through the season dislodged many of the tags.

The number-tags were essential for any further work on the pigs. Firstly a rough count was made and a sketch executed by a diver hovering over the pigs. Three principal concentrations of pigs could be seen. Next the pigs were trilaterated, using tapes stretched between pigs and then drawing up a plan of the ballast mound. Surveying divers carried sketch plans on the seabed and hovered above transportable 2-metre-square grids. By this means they were able to continually update the plan sections, detecting and recording many more untagged pigs. Archaeologists had expected, from observations the previous season, that there were some 60 pigs in all remaining on the site, but the more rigorous inspection allowed by the sketching process during the 1988 season revealed a total of 210 pigs, and it is clear that some more are yet concealed beneath the wreckage.

A transect position was chosen about midway through the large shoreward mound and marked on the site plan. However it was not until the fourth and final week of the season that the survey work was sufficiently complete to allow for excavation to commence. At that time the transect position was reassessed. It was apparent that to embark at that time on a transect through the centre of the mound would not be wise, because there was insufficient time to complete such a transect. Thus a new transect position was chosen, through the narrow shoreward extremity of the mound.

Pigs were chipped free across this transect. A number of cannon balls obstructing the removal of the pigs were also removed.

Neither hull timbers nor copper sheathing were found beneath the pigs of the inshore transect. The reef pan below the transect was devoid of holes. At the conclusion of the work remaining loose material was raised and the ballast pigs adjacent to the transect examined. They were found to be undamaged, and firmly secured by concretion to the seabed. It was clear that 'backfilling' would not be appropriate and that the ballast mound in general was in a condition similar to that found at the commencement of the excavation season.

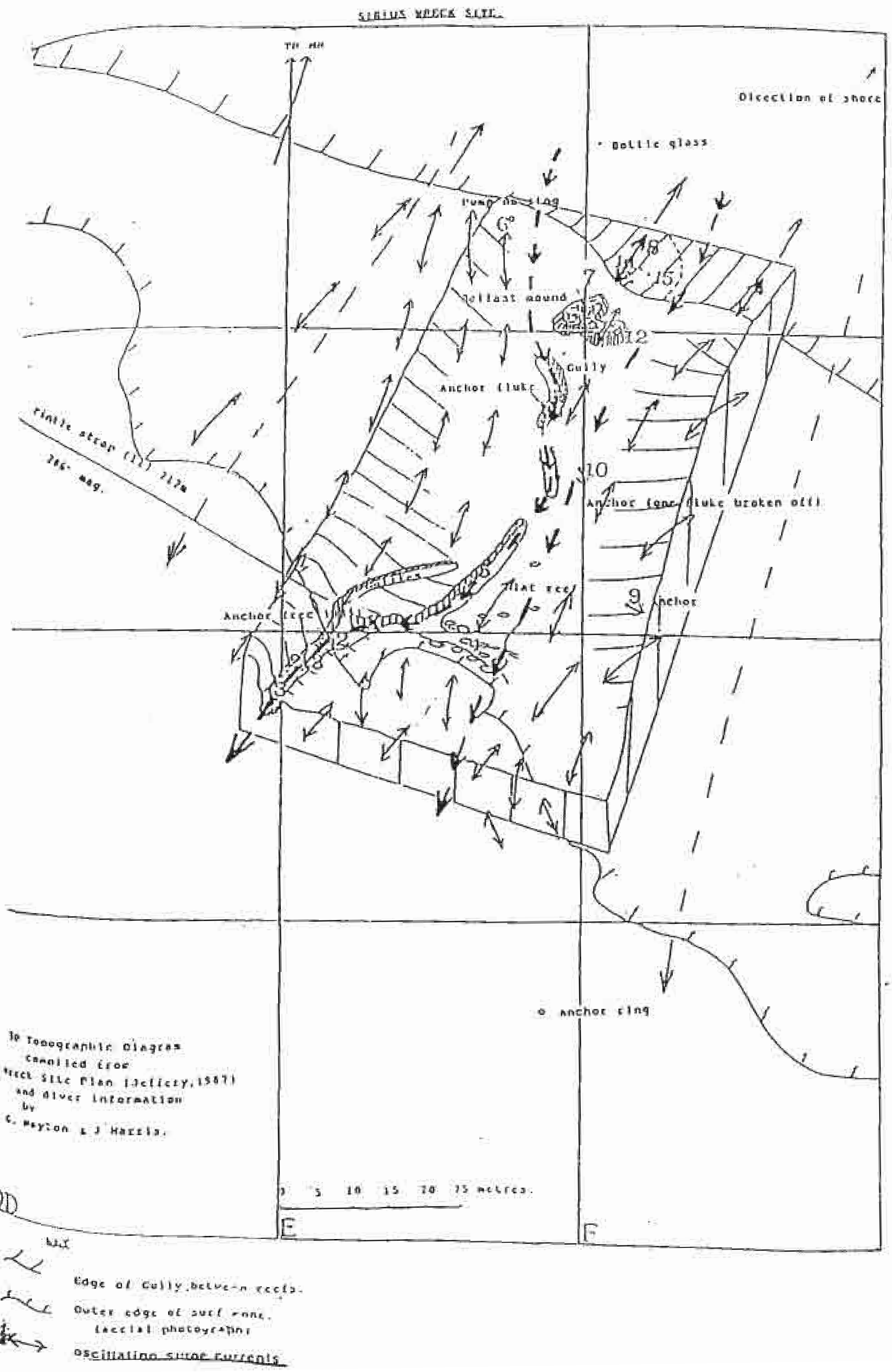
The two anchors remaining on the site were measured, and the loose anchor palm was raised for comparison with the anchor in Macquarie Place, Sydney.

Visual (and metal detector) examination of the site for other structural and fitting out revealed another anchor palm and what appears to be an iron knee. The anchor palm, still firmly attached to the reef, must indicate the original position of the Macquarie Place anchor, blasted from the reef in 1905. The solitary iron knee, located seaward and to the west of the ballast mound, may have been carried there by currents (see Nayton current diagram).

Research Design No.3

Data was collected in October 1988 with a view to establishing the rate of drift on the day the ***Sirius*** commenced offloading.

SEABED CURRENTS Gaye Nayton



B) Mapping the Wreck site.

Bill Jeffery, Senior Maritime Archaeologist, State Heritatge Branch, Department of Environment and Planning, Adelaide, South Australia

The mapping of the remains of HMS ***Sirius*** located off Norfolk Island during the 1988 expedition was one of the fundamental aims of the season's work as the work programmes which were centred around Henderson's hyphotheses required an accurate delineation of the nature and extent of the wreck site. The hypotheses being tested were;

- (a) that the *Sirius* ' ballast was secured;
- (b) that the matrix of ballast was partially maintained during and after the process of destruction of the *Sirius'* upper works;
- (c) that the matrix was sufficient to allow preservation of elements of the ship's bottom;
- (d) Gaye Nayton's model;
- (e) what correlation exists between the environment in which the wreck site is located and the quality of the archaeological remains

The permit issued by the Department of the Arts, Sport, the Environment, Tourism and Territories called for the preparation of a 'site plan'.

Mapping Procedures

An examination of the location of the wreck site will indicate the nature of, and the procedures used in mapping it. The site is the area 150 to 300 metres east of Kingston Pier, extending south from the high reef a distance of approximately 200 metres. The depth of water over this area varies from about 1.5 metres to 8 metres (north to south) with the main concentration of wreck material lying in 1 to 2 metres of water, depending upon the tide. The wreck site is lying predominantly on top of a flat reef with a small number of gutters of 1 to 1.5 metres in depth spread throughout the area. The shoaling nature of this area makes it very suitable for the southerly swell to break somewhere over the wreck site and rarely is there a day when no swell or break exists (Fig. 1).

These conditions make it extremely difficult to gain reliable measurements of the wreck site and the initial mapping work carried out in 1985 was completed from the shore base theodolite stations (Fig. 2). A flag or buoy was positioned directly above the artefact and horizontal theodolite angles were taken from two or more shore stations to allow for the triangulation of these artefacts. This system was repeated in the first part of the 1987 season until the main wreck site was located. It was found in this latter area that several iron ballast 'pigs' had accumulated and a more accurate system for recording them was needed. The difficulty with recording artefacts from shore base stations was that the flags or buoys were rarely directly above the artefacts because of the continual swell although several readings were averaged. The accumulated ballast pigs (ballast mound) was therefore mapped using a compass and tape measure underwater and only a reasonable outline was achieved (Fig. 3).

The 1988 season saw the need for a more accurate delineation of the wreck site and in particular the ballast mound, which meant all of the mapping would need to be carried out underwater. As described in the text by Henderson, several of the ballast pigs were marked with numbered tags (a total of 57) and these pigs were mapped by trilateration. It became evident during this exercise that there were many more pigs than expected, including two smaller separate mounds. Cleaning of sea-urchins and sea-grass which had adhered to the pigs made the identification and mapping of all pigs an easier task although they were never completely well distinguished from the surrounding reef.

The mapping of the remaining pigs was carried out using a prefabricated 2 metre square iron grid placed over several sections of the three ballast mounds and orientated around one or more numbered pigs to assist in the sketching of them. In this way all of the pigs and their orientation were mapped. The mapping of the positions of mounds and other wreck site artefacts, eg. carronade, anchors etc. was carried out using trilateration underwater although coordinated with previous shore-based surveys.

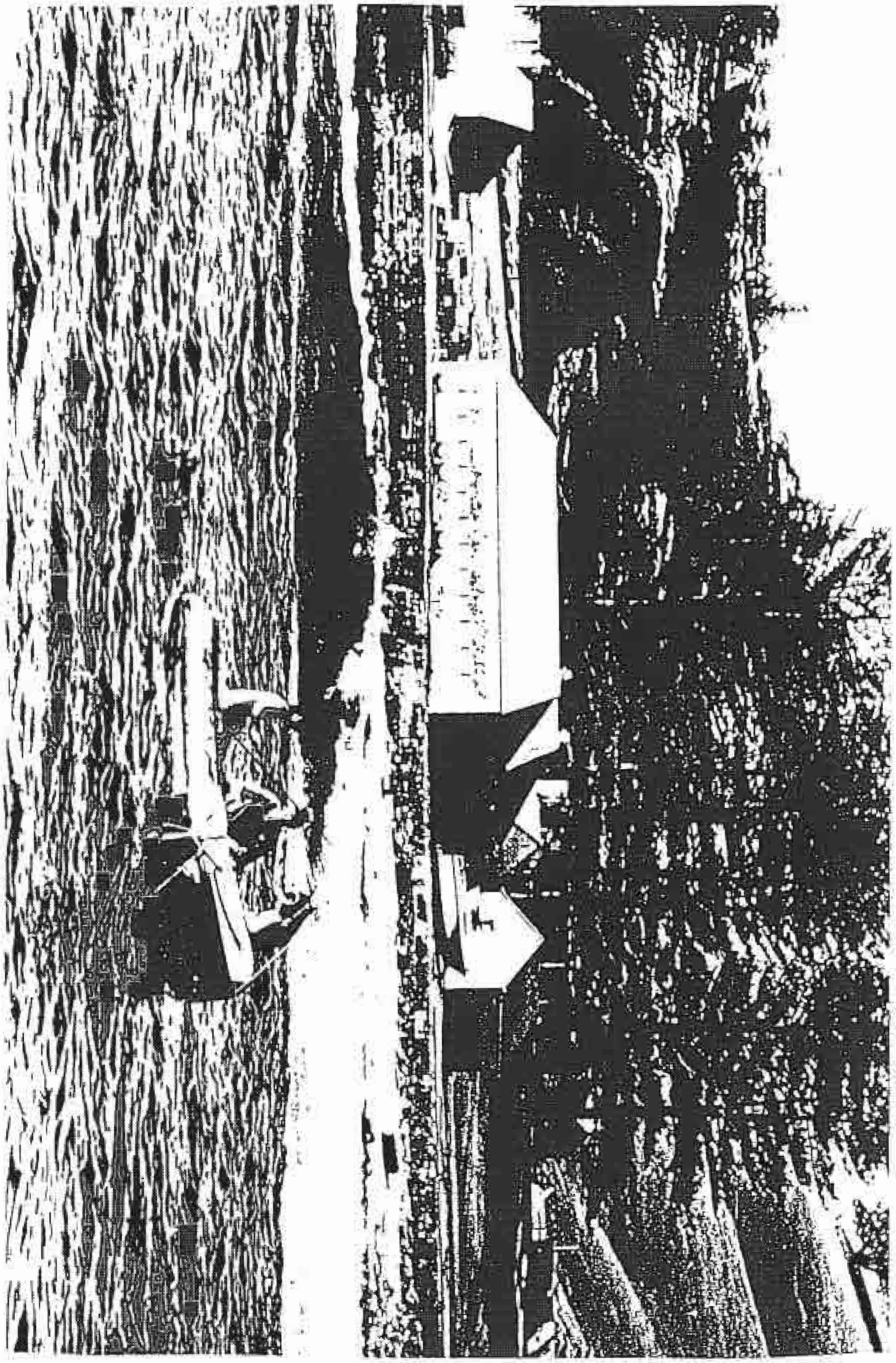


FIGURE 1

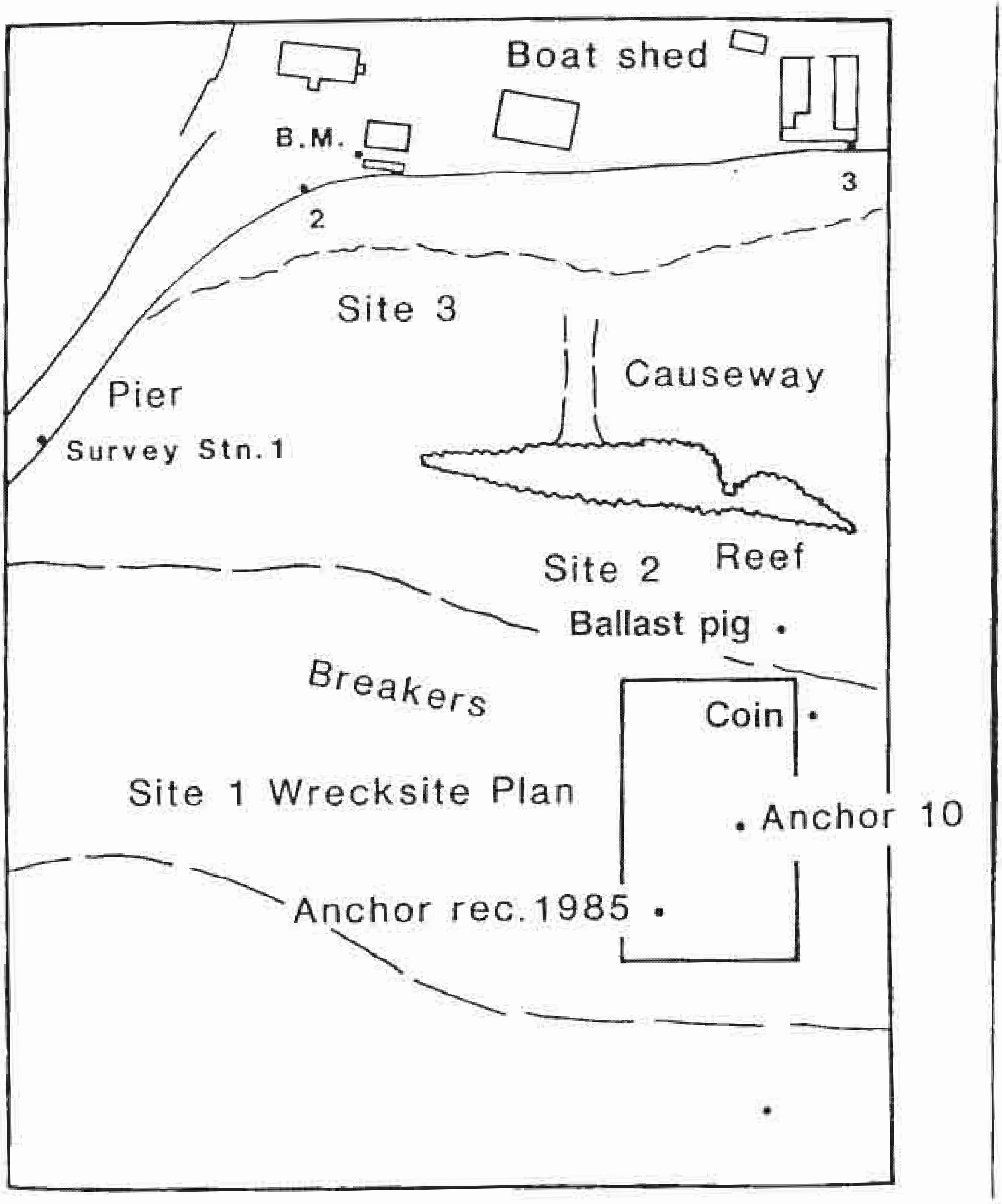
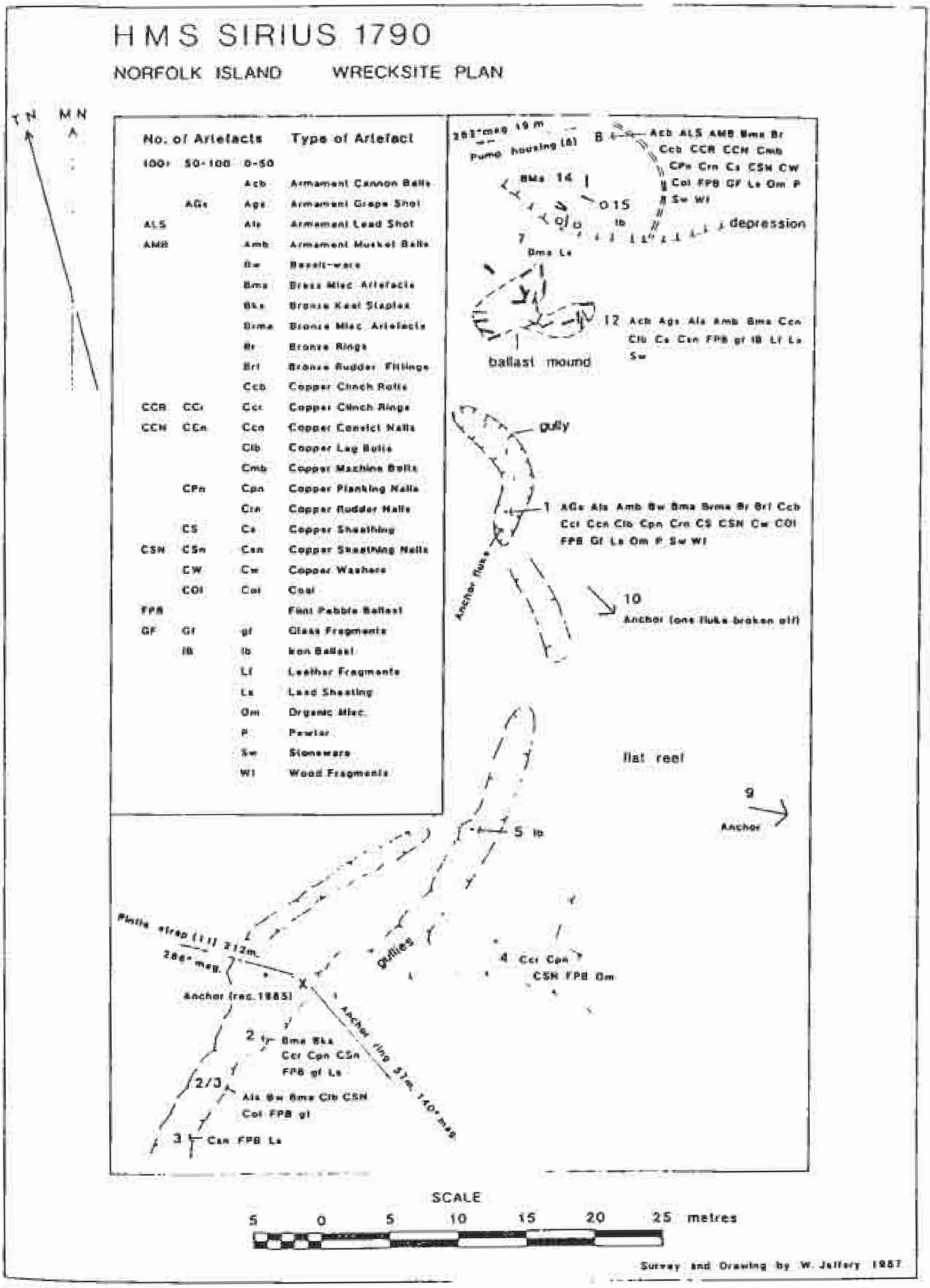


FIGURE 2 The shoreline, showing survey stations



HMS SIRIUS 1790
NORFOLK ISLAND WRECKSITE PLAN
TN
MN
No. of Artefacts
Type of Artefact
100+ 50-100 0-50
Acb Armament Cannon Balls
AGs Ags Armament Grape Shot
ALS Als Armament Lead Shot
AMB Amb Armament Musket Balls
Bw Basalt-ware
Bms Brass Misc Artefacts
Bks Bronze Keel Staples
Brma Bronze Misc. Artefacts
Br Bronze Rings
Brf Bronze Rudder Fittings
Ccb Copper Clinch Bolts
CCR CCr Ccr Copper Clinch Rings
CCN CCn Ccn Copper Convict Nails
Clb Copper Lag Bolts
Cmb Copper Machine Bolts
CPn Cpn Copper Planking Nails
Crn Copper Rudder Nails
CS Cs Copper Sheathing
CSN CSn Csn Copper Sheathing Nails
CW Cw Copper Washers
COl Col Coal
FPB Flint Pebble Ballast
GF Gf gf Glass Fragments
IB Ib Iron Ballast
Lf Leather Fragments
Ls Lead Sheeting
Om Organic Misc.
P Pewter
Sw Stoneware
Wf Wood Fragments
283°mag 19 m
Pump housing (6)
8 Acb ALS AMB Bms Br Ccb CCR CCN Cmb CPn Crn Cs CSN CW Col FPB GF Ls Om P Sw Wf
Bms 14
O 15
Ib
depression
7
Bms Ls
12 Acb Ags Als Amb Bms Ccn Clb Cs Csn FPB gf IB Lf Ls Sw
ballast mound
gully
1 AGs Als Amb Bw Bms Brma Br Brf Ccb Ccr Ccn Clb Cpn Crn CS CSN Cw COl FPB Gf Ls Om P Sw Wf
Anchor fluke
10
Anchor (one fluke broken off)
flat reef
9
Anchor
5 Ib
Pintle strap (11) 21.2m. 286° mag.
Anchor (rec. 1985)
Anchor ring 31m. 140° mag.
gullies
4 Ccr Cpn CSN FPB Om
2 Bms Bks Ccr Cpn CSn FPB gf Ls
2/3 Als Bw Bms Clb CSN Col FPB gf
3 Csn FPB Ls
SCALE
5 0 5 10 15 20 25 metres
Survey and Drawing by W. Jeffery 1987

FIGURE 3

It was found that the location of the wreck site material was more accurately defined using underwater survey techniques although current, swell and diver disorientation interfered with it. This was overcome to some extent by repeating the measurements on different occasions, under different conditions and using different divers to give mean measurements.

Mapping using photography in the form of photo-mosaics and stereo photography was attempted by Pat Baker, but the shallow depth of water, breaking swell and lack of contrast between the pigs and reef, made this method unsuitable.

The requirements of the work programmes meant that other features associated with the wreck site needed to be recorded, for example the underwater topography, water depth, currents etc. They all play a part in understanding the correlation between environment and wreck site condition. The main underwater topographical features and the wreck site is shown in Figure 4. A 5 metre grid was drawn over the whole plan to allow for coordination of all wreck site and topographical features. This grid is based on the measured direction of magnetic north (using a compass under water) which coincides with a line joining anchor number 10 and the eastern extreme of the main ballast mound. The origin of the grid was selected in the centre of this ballast mound as coordinates of other wreck site material would give an immediate impression of their distance from the 'final resting' place of HMS ***Sirius*** , ie the main ballast mound.

The information discernable from Figure 4 with consideration of the historical account in Henderson and Stanbury (1988), of the loss of HMS ***Sirius*** and the hypotheses put forward by Henderson is that:

1. The location of the anchor cut away when it was first found the vessel was in trouble is the position of the most seaward anchor ring. This is approximately 57 metres south-east of the anchor recovered in 1985. The outer anchor was recovered in 1973 and is now situated at the ***Sirius*** Museum in Kingston on Norfolk Island with a replica ring attached. It is the longest of the anchors found on the wreck site.
2. The two other very similar size anchors, one recovered in 1905 with a broken fluke, the other recovered in 1985 and the two carronades appear to be material dumped overboard in an attempt to lighten the ship and assist in the rescue of people and provisions (Henderson and Stanbury, 1988: 83). Three iron ballast pigs at positions 2/3, 5 and near the broken fluke appear to be material washed there sometime later during the destruction of the vessel as other smaller ballast and construction material is located there.
3. The next shoreward material, that of 65 ballast pigs and two broken anchors could well be the ballast which 'dropped out of her bottom' referred to by Hunter in Henderson and Stanbury, (1988: 86). Some of these pigs have maintained some relationship with other pigs, that is, a pair joined at one or more ends, while others are spread along the gully individually.
4. The main ballast mound, area 12 in Figure 3, appears to be the final resting place for HMS ***Sirius*** as according to Hunter in Henderson and Stanbury (1988: 86) '...the iron ballast having dropped out of her bottom, she was lifted fairly round, and was thrown more than her own length near to the shore, and was, by this change in her position, almost out of the reach of the break of the sea ...' The length of the ***Sirius*** was 89'83|4" which is 27.3 metres. The distance between the seaward ballast mound and the main ballast mound is 27 metres. From historical accounts this appears to be the most shoreward location of the vessel before it disintegrated on 1 January 1792. One hundred and twelve (112) ballast pigs are located here with 16 very close by to the west and slightly inclined down a gully while another 17 are slightly inshore, to the north. Only one additional ballast pig has been located directly inshore. The trail of anchor ring; anchors recovered in 1905 and 1985; outer ballast mound; inner ballast mound, provide the direction of wrecking for HMS ***Sirius.***
5. The appearance of the inner ballast mound suggests that while some disturbance has occurred to it during and after the process of wrecking, there are several pigs (many more than the outer mound) that have maintained a context with others, as pairs or in greater numbers. The outer mound was established at a time when the vessel was still moving shoreward; the inner mound was established in an area '... almost out of the reach of the break of the sea ...' and when the vessel had finally come to rest. It is

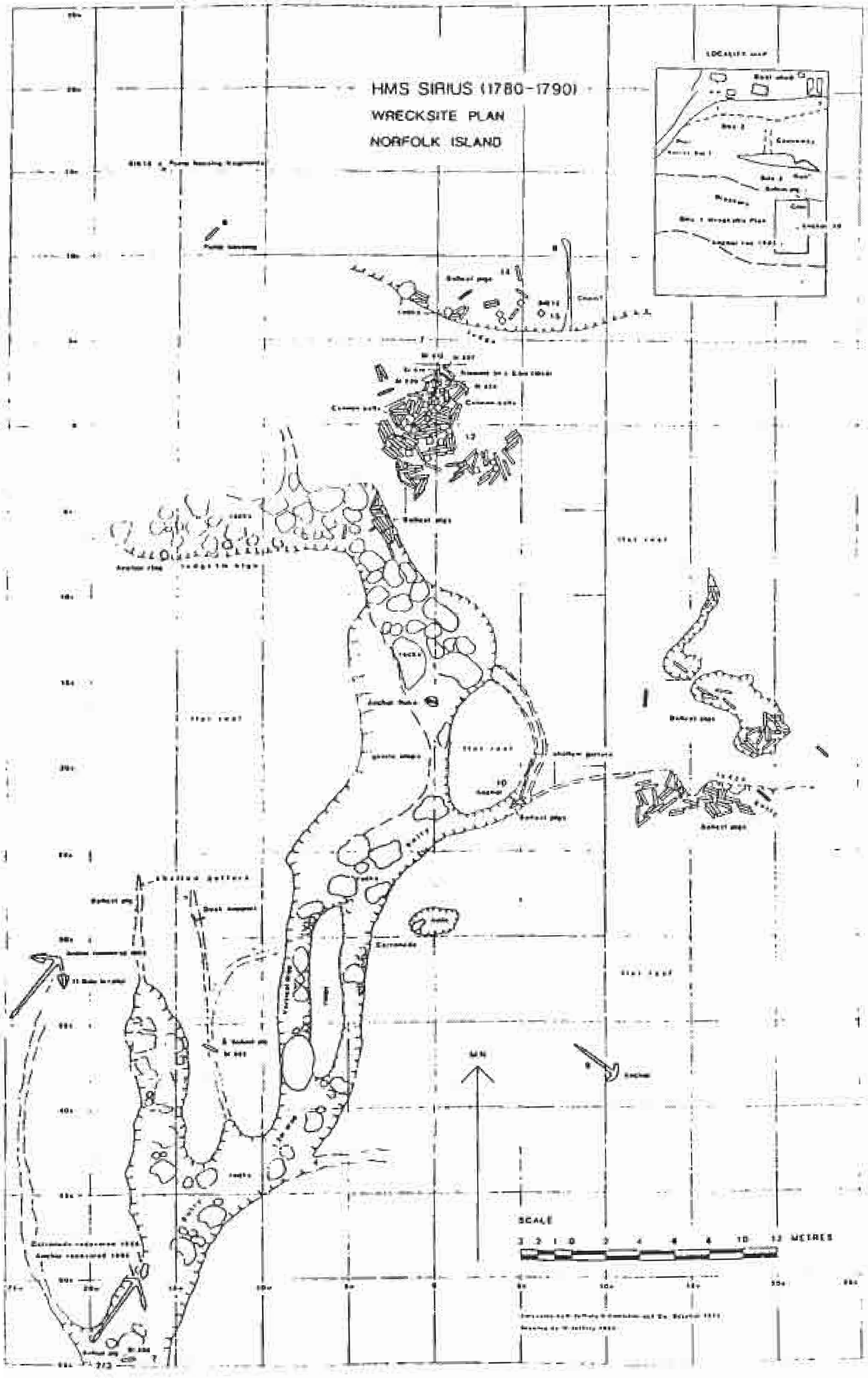

HMS SIRIUS (1780-1790)
WRECKSITE PLAN
NORFOLK ISLAND
SCALE
METRES

FIGURE 4

therefore reasonable to expect the inner mound will have a greater degree of correlation with the ballast as it was stowed in the bottom of the hull compared to the outer mound.

6. All of the wreck site material scattered on the reef is found laying in gullies or holes apart from the main ballast mound which is laying on a flat section of the reef. It is logical to expect the bolts, nails, washers, flint pebble ballast and other small artefacts should be found there but this is also the case with the 1.75 tonne anchors, carronades and 100 kilogram ballast pigs. The reason for this is most likely that these larger artefacts were moved by the action of the swell (a 1.0 tonne pyramid was moved in heavy conditions during the 1988 season) until they became lodged in such depressions. The likelihood of all this material being deposited in these depressions at the time of wrecking in 1790 seems too coincidental. The fact that the main ballast mound is still in context and lays out in the open on flat reef could also suggest that it was chained together permitting very few pigs to break away.

Mapping of the ***Sirius*** wreck site was carried out during all the permitted diving days and chiefly performed by Bill Jeffery and Maree Edmiston. However, all divers carried out some surveying.

C) Conservation of relics from HMS *Sirius*.

Ian MacLeod

Treatment of the *Sirius* Anchor (SI 57)

The treatment of the anchor raised in 1985 was finalised during the 1988 expedition and the object sent to the Australian National Maritime Museum on loan, with the aid of a Hercules aeroplane. The detailed conservation report and chemical analysis of the anchor are given in the body of the text but it is important to note that all the conservation work was performed on Norfolk Island itself. The final condition of the anchor is a credit to all of the personnel involved from it's recovery through the treatment stages and onto final display with its hand-crafted wooden stock.

In March 1985 the anchor was raised from the wreck site and brought alongside the Kingston jetty. A small section of concretion, approximately 50 cm x 10 cm, had come away as the anchor left the seabed. Within two hours the exposed part of the shank was covered with a red-brown iron (III) oxy-hydroxide film. Corrosion potential measurements on the anchor showed that the corrosion rate had increased significantly from its predisurbance value. Monitoring continued for 96 hours until the corrosion potential (Ecorr.) eventually plateaued at -0.340 volts vs AgCl. The shift of 240 mV in Ecorr. corresponds to a shift in corrosion rate from approximately 0.1 mm/year to 10 mm/year! Given that no commercial sacrificial anodes were available on Norfolk Island we improvised and attached 30 kg of aluminium-magnesium alloy engine blocks to the anchor using heavy gauge copper cable. Within a few minutes the Ecorr. value had fallen to its predisturbance value as shown in the Pourbaix diagram in Figure 1 (MacLeod, 1987). Pourbaix diagrams are thermodynamic stability maps which show whether a metal is in an active, passive (slow rate), or immune region with regard to corrosion. Measurements on the anchor showed that it was in an active corrosion zone - the less negative (more positive) an Ecorr. the faster the rate of corrosion for base metals such as iron.

The anchor was left in shallow water which was well oxygenated by the surge and wave action. The warm sea water (20.80± 1.96° C) and salinity of 35.77± 0.04 ppt meant that the aluminium should corrode at a rapid rate and provide the necessary current, since the chloride ions would break down the normally protective layer on the metal. The anchor was left in this state until the treatment tank was built and a conservator, Jon Carpenter, was available to carry out the next stage of treatment.

Inspection of the anchor after one year of cathodic protection showed that the 'scar' on the shank was healed and that the copper cable was also covered with a white calcareous layer. The anode had lost half of its weight and the corrosion potential of the anchor at -700 mV vs AgCl was 120 mV more negative than its predisturbance value, which shows that it had been effectively protected from any corrosion during the year in the sea by the pier. Although no surface pH measurements were made, the Ecorr. value corresponded to a redox potential (Eh) of -0.43 volts vs the Standard Hydrogen Electrode (SHE) and a pH value of 7.43, assuming that hydrogen gas is in equilibrium with the acidity of the solution. This pH represents a reduction in acidity by a factor of more than four hundred during the year of cathodic protection. On breaking the concretion seal copious amounts of gas were released which is not surprising when considering the reduction of acidity viz. as the electrons flow in, hydrogen ions will be reduced to hydrogen gas and the chloride ions will diffuse out, viz.

$$H^+ + e^- \rightarrow \tfrac{1}{2} H_2$$

Recent work on a concreted iron cannon from the ***Batavia*** (1629) has shown that chloride ions diffuse out from the dense concretion under the influence of the electrical current flowing from the sacrificial anode and at rates up to 8.7 g m^{-2} $hr^{-1/2}$ (MacLeod, 1988). Based on a net consumption of 7 kg of aluminium the approximate current density delivered by the engine block anode to the anchor was of the order 150 $mA.m^{-2}$ which will protect iron metal from corrosion in the marine environment (Fischer, 1983: 110).

The anchor was deconcreted by Jon Carpenter and set up for electrolysis in a custom built T-shaped steel tank at the Works Depot where it had been fabricated. The details of the procedure

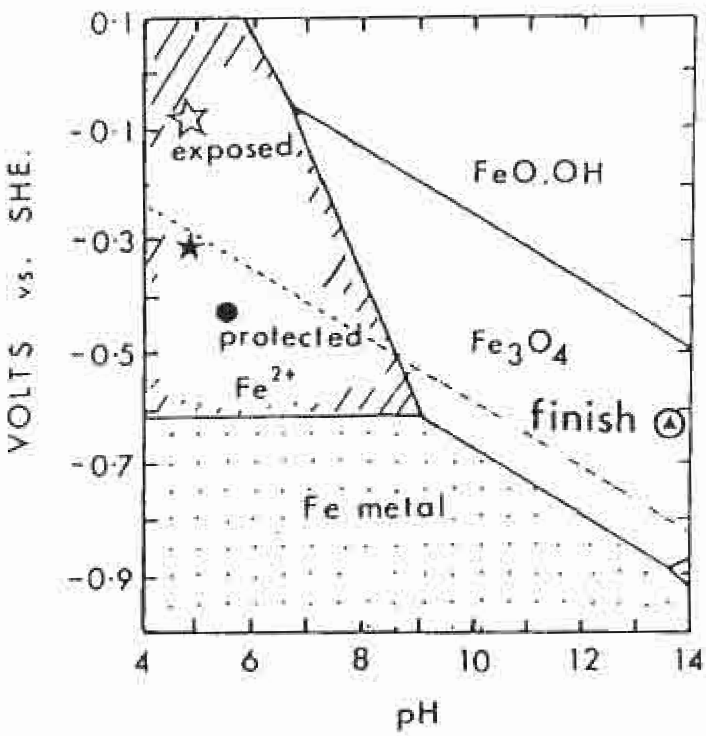
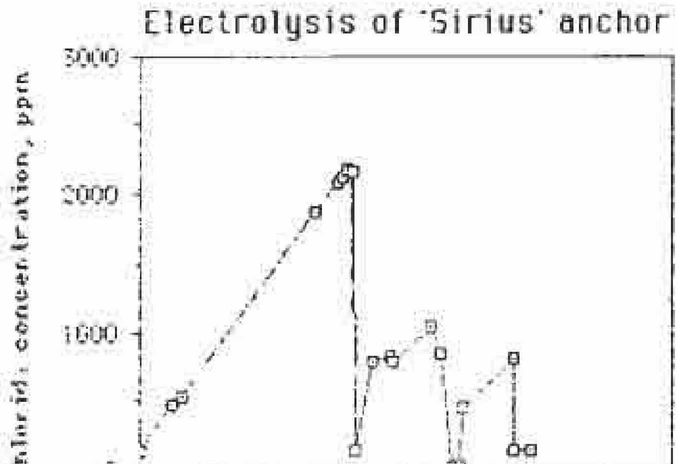


Figure 1 Pourbaix diagram for iron and water at 25 °C with soluble species at 10^{-6} M concentration. Data from Fig. 2 corrected to Standard Hydrogen Electrode scale (Ag/AgCl sea water reference electrode +0·268 volts *vs* SHE). *Predisturbance corrosion potential of *Sirius* anchor, ☆ after 4 days, ● after one year of cathodic protection.



Electrolysis of 'Sirius' anchor
Chloride concentration, ppm
3000
2000
1000
0
0
100
200
Square root of treatment time (hr 1/2)

FIGURE 2

are fully described in his report (Carpenter, 1986). A summary of the chloride concentrations in the wash solutions is shown in Table 1 and is illustrated in Figure 2 where the amount of chloride ions in a solution is plotted against the square root of the treatment time ($hr^{1/2}$) The initial response of the anchor conforms to the normal behaviour of a diffusion controlled process in that the chloride concentration increases linearly with the square root of treatment time. The data for the first 230 days of treatment can be summarised by the relationship

$$[Cl]\ ppm = 26.11\ t^{1/2} + 143$$

The correlation coefficient for the least squares fit is 0.99984; the intercept at zero treatment time had a value of 143 ppm which is typical of the chloride content found in the water from the airport bore which was used to make up the solution. Given that the solution volume is 7000 litres the release rate corresponds to 183 grams of chloride ions per $hour^{1/2}$, or approximately 35 $grams.m^{-2}\,hr^{-1/2}$ (based on a surface area of 5.2 square metres). In the first wash, 58% of the total chloride ions released in the 891 days of treatment reported to the solution. A total of four wash solutions comprising of 200 kg sodium hydroxide and 28 tonnes of water were used in the treatment programme. Inspection of the graph in Figure 2 shows non linear responses of the chloride concentration with square root of treatment time in the second and third wash. The different behaviour is probably due to the variations in electrolysis conditions viz., sometimes on / sometimes off (depending on whether the carronade or anchor were connected to the D.C. power source) and on the concentration of the electrolyte.

The final wash solution showed no increase in chloride ion concentration over a period of seventy five days and the final value of 138 ppm was the background level found for the airport bore. Samples of metal were drilled from the shank, a palm and a fluke and analysed for chloride ions, with the resulting levels being 0.015 wt%, 0.015 wt% and 0.026 wt% respectively. The anchor showed negligibe flash rusting after standing overnight in the heavy dew which further indicated that the metal had been stabilised.

Results and discussion.

Inspection of the anchor at the end of the treatment programme showed that large areas of original surface had been retained. It was noted during the deconcreting process that the calcareous matrix was extremely hard (Carpenter, 1986) and that the underlying metal was not so prone to spalling as is generally found with wrought iron anchors that have been in the sea for several hundred years. The most likely explanation for these features lie in the pretreatment that the anchor received during its year of cathodic protection lying alongside Kingston jetty. It should be noted that most of the original surface has very little mechanical strength and is very prone to disbondment. The properties of the various zones of wrought iron has been well documented by Chilton and Evans (1955) and they relate to the distribution of impurities in the bands of metal and their effect on the corrosion mechanism. In the extensive hot working of the final surface the iron was decarburized and sulphur impurities would have been removed by oxidation. Prior to treatment the anchor was sampled by drilling and the results are shown below in Table 2.

Table 2.Composition of *Sirius* Anchor, weight %

	Carbon	Sulphur	Silicon	Nickel	Copper	Manganese	Phosphorous	Chloride
outer layer	0.25	0.05	0.20	<0.005	0.015	0.090	0.035	1.12
inner zone	0.10	0.04	0.10	<0.005	0.015	0.015	0.15	0.61

The total amount of chloride released from the anchor was approximately 1.63 wt% which is consistent with the above data since the analyses refer primarily to the metal rather than a mixture of iron and corrosion products, which would have more chloride in them. The low level of sulphur in the anchor indicates that the wrought iron had probably been produced using charcoal rather than coal as the reducing agent in the furnace. Given that nickel and copper promote the zonal corrosion which results in the typical woodgrain finish of corroded wrought iron, the low levels of these noble metal impurities will have helped in reducing the localised corrosion rate, and so help retain vestiges of the original surface.

The corrosion potential of the anchor was measured prior to its removal and at a pH of 13.62 the Ecorr. was -0.636 volts vs SHE, which is seen in the Pourbaix diagram (Figure 1) to be in a passive state. The surface was covered with a dense black layer of magnetite (Fe_3O_4). After rinsing the surface with fresh water it was allowed to dry in the sun. The anchor was given an initial protective coating of a proprietary rust proofing agent, 'Gold Seal' which had been thinned with mineral turpentine to facilitate penetration and to prevent flash rusting and to partially consolidate the friable surface. Subsequent coats of the sealant have provided temporary protection from corrosion. It should be noted that the surface of the anchor could have easily been lost if the electrolysis treatment had been too severe. Despite a succession of people being responsible for the analysis of the treatment solutions a good set of treatment records exist.

A formal representation of one of the many processes occurring during the cathodic protection of the anchor could be summarised by the equation

$$2\ FeO.OH + FeCl_2 + 2e^- \varnothing Fe_3O_4 + H_2 + 2Cl^-$$

namely a mixture of iron (II) and iron (III) corrosion products are changed from the reactive and inherently acidic forms to the stable black corrosion product magnetite (Fe_3O_4). In the same process the chloride ions diffuse through the concretion back into the surrounding sea water and the acidity of the solution under the concretion is reduced. The reduction in acidity shifts the iron metal towards a more stable situation. Since the acid from metal ion hydrolysis had dissolved calcium carbonate, the reduction in acidity will tend to promote redeposition of calcium/magnesium carbonates (magnesium calcites) and the deposition of the iron carbonate siderite ($Fe\ C0_3$). Such a redeposition would harden the concretion and combined with the production of more magnetite it would act as a 'cement' to bind together the original surface material which normally falls away from the corroded metal. The filamentous nature of the slag inclusions ($Si0_2.2Fe0$) may act as a reinforcing matrix for the redeposited minerals.

Recommendations

The object is the best preserved example of a ship's anchor that has been recovered from an Australian historic shipwreck site. The anchor represents the pinnacle of 18th century craftsmanship in producing massive wrought iron objects. Every effort should be made to ensure its preservation. Once housed inside a suitable museum environment the wooden stock should be fitted so that the proper functional mode of the anchor is readily apparent. At this stage the temporary surface coating can be removed and the anchor given a proper inhibitive coating in conjunction with a moisture barrier.

Given the success of this method of treating an historic wrought iron anchor, serious thought should be given to adopting this technique when developing management plans for shipwreck sites. The traditional sand-blasting and controlled weathering techniques may well need to be reassessed. During a site survey, sacrificial anodes could be attached to an anchor - if no excavation follows then the life of the anchor will have been extended. If the object is recovered then the pretreatment will have enhanced the archaeological and aesthetic values.

Copper Alloys

Treatment of copper based artefacts recovered in the 1987 season was concluded during the 1988 season. The work consisted primarily of removing secondary mineralisation from the surface of all the copper bolts, nails and sheathing. A blue-green patina had formed during extended washing in sesquicarbonate solutions and since it had no relevance with regard to on-site conditions it was chemically removed using thiourea inhibited 2wt% citric acid followed by a bicarbonate rinse and a coating with Incralac.

Cannon Balls

The cannon balls were all deconcreted, measured and weighed before being stored in 2wt% sodium hydroxide solution. After preliminary passivation, two 80 litre tubs of 4wt% sodium hydroxide and 5wt% sodium dithionite were used to begin chemical reduction of the corroded and heavily graphitized iron cannon balls. The tubs were protected from the ingress of oxygen by a layer of liquid paraffin which was poured over the treatment solutions containing the objects. Measurements of the corrosion potentials and the solution pH confirmed that the cannon balls were in a strongly reducing and alkaline environment. These conditions prevent any further oxidation of the residual metal and promote reduction of corroded iron to the stable block corrosion product magnetite (Fe_3O_4) in much the same way as does conventional electrolysis. These conditions are optimum for the release of chloride ions from the corroded objects. The treatment of the cannon balls by this method will take several years.

Iron Ballast

The iron ballast recovered during previous expeditions was treated along with the material covered in 1988 using the electrolysis tank previously occupied by the ***Sirius*** anchor. A series of electrical connections was made, one to each ballast block and the anodes that had been used with the anchor were refurbished. The cathodic dc current was passed through the ballast to effect the treatment. This work began on the 30 October, 1988 and has been continued by Bevan Nicolai.

The analysis of the data listed in the table below show that the chloride ions are being released at a regular rate and conform to the equation,

$$[Cl]ppm = 10.3t^{1/2} + 18.4$$

in a solution volume of approximately 7000 litres. A release rate of 10.3 parts per million per hour 1/2 means that in one period of unit time approximately 72 grammes of chloride ions are being released. The approximate surface area of the ballast pigs is of the order 40110 cm^2 which can be expressed as 4·011 m^2 which gives a release rate of 18·0g $m^{-2}hr^{-1/2}$. Knowing the surface area of the objects we can compare the efficiency of the electrolysis. For example the ***Sirius*** anchor released chloride ions at the rate of 35g $.m^{-2}.hr^{-1/2}$

The comparison of the wrought iron anchor with the cast iron ballast pigs is not necessarily all that strong and so it is best to compare it with anther cast iron object such as an extensively corroded ***Batavia*** cannon. The concreted and cathodically treated ***Batavia*** cannon was found to be releasing chloride ions at essentially the same rate as the ***Sirius*** ballast pigs.

Electrolysis treatment of *Sirius* ballast

Date	Time hr	Time $hr.^{1/2}$	[Cl]ppm
30.10.88	0	0	60
15.11.88	384	19.6	188.5
22.12.88	1272	35.67	139
19.01.89	1944	44.09	451
07.02.89	2400	48.99	434
20.03.89	3384	58.17	710
21.06.89	5616	74.94	795

More interestingly a comparison of the chloride release rates from the ***Sirius*** carronade at the early stages of electrolysis was of the order of 754g$.m^{-2}.hr^{-1/2}$ whereas when it was just sitting soaking in caustic the chloride release rate was 47 g$.m^{-2}.hr^{-1/2}$. This comparison indicates that the chloride ions from the ballast are not releasing at the rate that would be expected given their average extent of corrosion. There may be problems with the concentration of electrolyte in the treatment tank.

The actual weight of the ballast pigs recovered to date is not known since accurate scales were not available for use at the Works Depot and the individual weight of the objects was not sufficient to be measured with any accuracy on the computerised scale on the Kato crane. However on the basis of the dimensions and using the known density of grey cast iron we have calculated that the weight of pigs recovered to date is approximately 1308 kg and is such that the amount of chloride released as of 21 June, 1989 corresponds to approx 0.42 wt.%.

Given that the total amount of chloride released from something like the cannon from the ***Rapid*** wreck site, which was from very sheltered conditions, amounted to 1.65 wt.% and the amount of chloride removed from the *Sirius* carronade was 5.24 wt.% this again indicates that the treatment for the ballast is far from complete.

Sirius Carronade

The treatment of the ***Sirius*** carronade recovered in 1985 has continued very satisfactorily and during the 1988 expedition it was possible to collate all the chloride analyses carried out by the wide variety of people over the last few years and to plot the data and to present it in a meaningful form.

After 3 years of treatment the cannon is now ready for the final stages which will include the washing in fresh water to remove excess sodium hydroxide followed by washing in deionized water or fresh rainwater with corrosion inhibitors to prevent the flash rusting of the stabilized cannon. This should then be followed by dewatering and wax impregnation. The wax impregnation facilities of the WA Museum conservation laboratories or those of the Queensland Museum laboratories would be suitable for this process. An alternative approach wouldbe to transport a small wax tank to Norfolk Island and impregnate the cannon on site. This would minimize any chance of possible damage to the extensively corroded surface. The most remarkable feature with the electrolysis of the ***Sirius*** carronade is that it would appear that the more extensively corroded surface is able to release chloride ions, under the optimum conditions of electrolyte concentration and current density, at a far greater rate than we have observed with less extensively corroded cannon such as that recovered from the American China trader the ***Rapid***. The chemical composition of the carronade is listed below:

	C	S	Si	Ni	Cu	Mn	P	Cl
Sirius (1790)								
outer zone	13.4	0.16	3.35	0.040	0.025	0.15	1.20	2.19
inner zone	3.5	0.08	0.10	0.015	0.015	0.48	0.57	0.192

Summary of treatment data for electrolysis of *Sirius* carronade

Date	[Cl]ppm	Time hr	hr $^{1/2}$
21.03.86	941	0	0
31.03.86	1017	240	15.5
10.10.86	2606	4872	69.8
18.10.86	2641	5064	71.2
23.10.86	2733	5184	72.0
30.10.86	951	5352	73.2
29.01.87	2299	7536	86.8
21.03.87	2646	8736	93.5
23.03.87	1530	8784	93.7
10.07.87	301	11544	107.4
28.07.87	1254	11832	108.8
02.09.87	718	12672	112.6
20.01.87	10	13752	117.3
21.12.87	1884	14496	120.4
24.04.88	7666	18192	134.9
21.07.88	7814	19584	139.9
21.07.88	140	19584	139.9
04.10.88	215	21384	146.2
18.10.88	250	21720	147.38
21.10.88	536	21792	147.62
15.11.88	227	22392	149.63

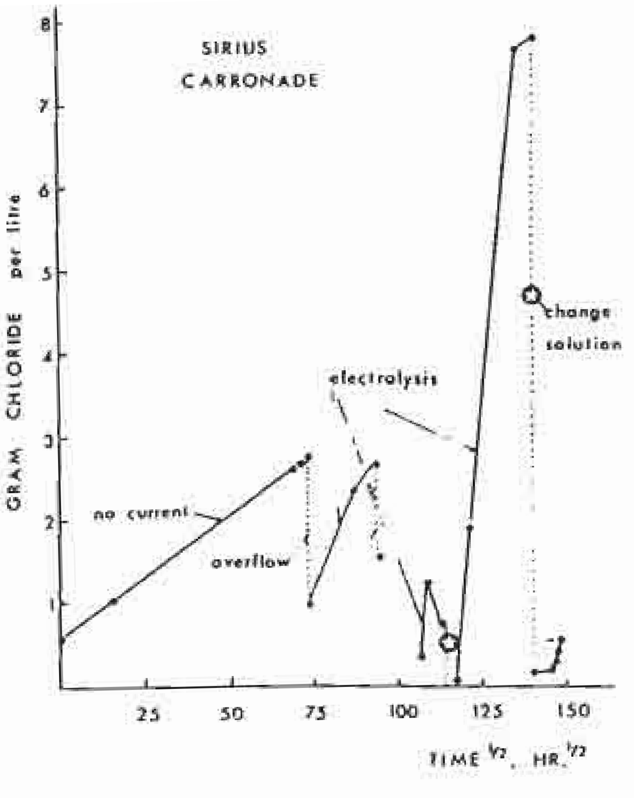


FIGURE 3 Plot of chloride concentration and the square root of treatment time for the conservation of the Sirius carronade.

19.12.88	60.5	23208	152.34
19.01.89	99	23952	154.76
07.02.89	88	24408	156.23
28.03.89	107	25584	159.95
21.06.89	-	27624	166.20

A graphical representation of the data shows that the distinct periods of an irregularity in release rates correspond to problems such as tank overflow during periods of excessive rain. This problem was overcome by building covers for the treatment tanks which minimised problems of losses of electrolyte and problems of too much evaporation of the solution. To date the amount of chloride ions removed from the ***Sirius*** carronade correspond to 25.5 kg or approx 5.24 wt.%. Examination of the incised markings on the carronade show that there is an unclear number in the hundred weight (cwt) section but clearly 2 quarters and 9 pounds. There has been debate as to whether the initial weight of the carronade was 8cwt or 9cwt. However, we have been able to show on the basis of the analysis of the chloride ions removed from the carronade and the amount of iron that has been lost to the concretion (approx. 38 kg) that the only possible weight the cannon could have had was indeed 9cwt 2 qr and 9 lb. Thus the conservation treatment of the carronade has solved an archaeological problem. One apparent advantage of the greater extent of the corrosion of the ***Sirius*** carronade is that the last 5% of the chloride ions extracted to date have come out within the space of one year whereas in other treatments with less extensively corroded cannon the last 5% extracted will take a period of at least 1 to 2 years more to be removed under electrolysis conditions.

Maravedi Coin

A small copper coin was recovered from the area away from the main site between the inner ballast mound and the shore by Terry Arnott. Close examination showed that it was a coin belonging to Charles the III of Spain. The diameter of the coin and its apparent original thickness was used to calculate the denomination as a two-maravedi piece. The comparison was based on known copper coins of the period. The date after treatment was shown to be the year 1774. The coin was probably picked up by a First Fleet officer or crew member of the *Sirius* when they called at Teneriffe. Owing to the extremely delicate and extensively corroded nature of the service of the coin it was decided that the stabilization should be carried out by using a two stage process which involved an initial desalination in the distilled water followed by localized consolidative reduction using the alkaline dithionite method. Analysis of the conductivity of the solution showed that within the space of 64 hours the solution had reached an initial plateau level. After the solution change the conductance increased until approximately six days had elapsed. Following the dithionite treatment of the coin it was given a protective coating of micro-crystalline wax.

Desalination of the 2-Maravedi coin

Date	Time	Conductance μs	Time hrs	$Time^{1/2}$
16.10.88	0	23.8	0	0.0
17.10.88	10	99.7	18.0	4.24
17.10.88	14.3	116.5	22.5	4.7
18.10.88	8.4	122.6	40.4	6.36
18.10.88	16.3	122.0	48.2	6.94
19.10.88	9.0	119.4	64.7	8.04
19.10.88	9.0	5.2	64.7	8.04
19.10.88	17.3	15.5	73.2	8.56

20.11.88	10.3	25.5	90.2	9.50
21.10.88	10.3	29.8	114.2	10.69
22.10.88	13.3	32.5	141.2	11.88

Inspection of the treated surface revealed the mint mark of Segovia and as such the coin is rather rare. The exchange rate in terms of the number of maravedi per real varied but on the basis of 32 maravedi per real and 8 real per dollar the total sum of 256 maravedi per piece of eight meant that in common terms the 2-maravedi piece was equivalent to about a British half-penny.

On-Site Measurements.

During the survey period, when the ballast was being tagged and plotted, samples of weed were collected from the main wreck site. Samples were recovered from the ballast pigs, from the general area around the anchor, from the growth on the anchor ring and from the general reef top and growth on the anchor itself. There appears to be no systematic difference in the species due to the presence of iron or its corrosion products. This is consistent with the fact that the colouration of the concretion on the wreck site is essentially that of the surrounding coralline environment in that there are no characteristic iron stains and the species are essentially that which are expected from a shallow high energy habitat.

The researchers at Murdoch University stated that if there were any effects, the crustose coralline algae would be more likely to show them than the erect algae. We know from our previous work on comparing the rate of concretion formation on iron artefacts from a wide variety of wreck sites in tropical and sub tropical waters that the amount of phosphorous in the metal has a major dominating effect on acceleration of concretion formation. However, the analysis from the soft algae growth on the wreck site is important in gaining an overall understanding of the way in which the material has degraded on the site itself and the high energy habitat of the wreck site which was also confirmed by our measurements of on-site parameters of corrosion potentials and pH.

Distribution of erect algae on the *Sirius* wreck site

Species	Anchor ring	Anchor	Ballast pigs	Reef platform	Anchor surrounds
Depth	3-5 m	3-5 m	3-5 m	1-2 m	3-5 m
Zonaria disingiana	x	x	x	x	x
Amphiroa sp	x	x	x	x	x
Pterocladia capillacea	x	x	x	-	x
Plocamium preissianum	-	x	x	-	-
Laurencia filiformis	-	x	-	-	-
Laurencia brongniartii	-	x	-	-	x
Laurencia botryoides	-	-	-	x	-
Galaxaura oblongata	-	-	-	x	-
Champia sp				x	-
Dilophus intermedius	-	-	-	-	x
Maliptilon roseum	-	-	x	-	x
Antithamnion hanowoides	-	-	x	-	-

At the start of the 1988 season it was decided to undertake a survey of the corrosion potentials and pH measurements on the corroded iron underneath the protective layer of concretion. Such a survey would be a very valuable asset to conservators and corrosion scientists since, for the first time on a major shipwreck site, there was a statistically large enough number of apparently identical objects which had corroded in the same environment to enable proper assessment of the reliability of corrosion potential measurements as an index of corrosivity of the site. One of the biggest problems that has been faced over the last 10 years of accumulating data is that there have only been one or two cannon, one or two anchors available for measurement on a given site. Since many of the sites are in locations where there are different water temperatures and different effects of marine growth, it is very hard to see if there are any overall correlations.

With this objective in mind, a series of corrosion potential and pH measurements were made on the ***Sirius*** pigs and on the two remaining anchors once they had all been surveyed. This work was delayed until the pigs had been tagged so that we could properly relate the measurements to individual objects whose position was precisely located on the site plan. It was rather surprising to find that a large degree of variation existed in the corrosion potential measurements. It had been anticipated that a spread of perhaps 20 or 30 millivolts may be found whereas in fact the difference between the highest and the lowest corrosion potential was greater than 160 millivolts rather than a few tens of millivolts. These differences indicated that the objects were showing markedly different corrosion rates.

Inspection of the artefacts previously raised in other expeditions showed that there was indeed a wide range of corrosion behaviour of the same cast iron objects in the form of ballast. The least corroded ballast pig had been recovered from the lagoon area in 1985 whilst the most corroded pig had been recovered in 1987 on a section of the site that was quite exposed. Under the strong surge conditions experienced on the site the measurement of surface pH is very difficult. Owing to the advantage of having a compressed-air driven drill with a 12.5 mm masonary bit we were able to drill into the protective concretion layer and insert a pH electrode with the same external diameter. The electrode has a specially prepared flat glass bulb which is extremely sensitive and delicate.

Working with such instruments under the given site conditions is not easy. However, we were able to obtain some very useful parameters in that we were able to record the lowest ever observed pH value of 4.18 under the concretion of a ballast pig. Previously the most acidic micro environment recorded on any iron artefact which were recovered from the ***Batavia*** wreck site on the Abrolhos Islands where the typical value were 4.8, a factor of more than four times less acidic. It should be noted that most measurements for pH and corrosion potential were taken on the down current side of an object so that any affects of the current would be minimized. The amount of water movement inside the drilled section was very small since the diameter of the pH electrode and the drill was the same and therefore it was a very snug fit. Inspection of the digital read out of the pH meter showed that equilibrium values were obtained within a period of 30 seconds to a couple of minutes. It should be noted that owing to the site conditions it was not possible to insert the pH electrodes as quickly as we would have liked since the wave action was often extreme. Our measurements have confirmed that the HMS ***Sirius*** site is the most aggressive of all those measured by this team. A summary of the pH and corrosion potential measurements is shown in the Pourbaix diagram for iron in sea water on the ***Sirius*** site. It should be noted that essentially all the objects have corrosion potentials that are in the active region for corrosion. The only object close to a passive state was a detached anchor palm. Analysis of the corrosion potentials and pH measurements showed that, despite the difficult working conditions, a definite relationship between pH and Ecorr. exists. The corrosion process is related to the surface pH through the partial hydrolysis of the primary corrosion product, ferrous chloride viz

$$Fe \quad Fe^{2+} + 2e^-$$

$$FeCl_2 + H_2O \quad 1/2(FeCl_2 \cdot Fe(OH)_2) + H^+ + Cl^-$$

The above phenomena are reflected in the on-site variables which conform to the relationship

$$E_{corr}^{wrought} = -0.029\ pH - 0.100$$

The cast iron objects show the same pH dependence as the wrought iron anchors and anchor fluke but the intercept values are different. Corrosion potential measurements on the second carronade found on the site indicated that it was undergoing active corrosion. Since it is planned to recover the carronade once the first one has been finished and placed on display it was decided to begin treatment of the object on the sea bed in the same way as the ***Sirius*** anchor had been treated. Geoff Kimpton and Franklin Randall fabricated a very sturdy bracket and used heavy duty insulated battery cable to connect it to twenty kilograms of welded aluminium alloy engine blocks. The corrosion potential of the carronade was re-measured immediately prior to the attachment of the anode and it was within 10 millivolts of its previous value which showed that the process of drilling into the concretion and measuring corrosion potential has very little affect on the overall corrosion rate. If there had been a major effect we know from previous experience that the corrosion potential would be at least 100 millivolts more positive than its previous value.

Within a few minutes of attachment of the anode it was possible to re-measure the corrosion potential which showed it had dropped by more than 160 mv which is indicative of good electrical contact and current flow into the cannon. Photographic records of the anode one week later showed extensive surface modification of the aluminium alloy indicating good cathodic protection. During violent storms at Kingston in the middle of 1989 it was reported that the bracket had become dislodged from the cannon and so this protection was no longer operative. This loss of the protective mechanism is not totally unexpected given that the site conditions in a storm can easily shift the 1.0 tonne oblisk some 20 metres across the sea bed.

Corrosion potentials and water depth

During the expedition it became apparent that there appeared to be a correlation of corrosion potential with water depths. The pigs that showed the most high (the least negative) corrosion potentials were found in the shallowest water whilst those with more negative values reflecting less corrosive environments were found in deeper waters. It should also be noted that for a given water depth the higher the profile of the object on the seabed the more responsive the corrosion potential was to the combined effects of water movement and dissolved oxygen.

Owing to the difference in chemical composition of wrought iron and cast iron it is not possible to make a direct comparison of the corrosion potential of one type of iron alloy with the other. However it should be noted that the anchor that lay in the shallow part of the *Sirius* site had a higher corrosion potential than the anchor in the deeper waters . In order to assess the implications of these observations the data previously collected on a variety of wreck sites was compared with that of ***Sirius***. Cast iron objects were compared only with other cast iron objects in this category items such as the cast iron propeller of the steam ship ***Xantho***, trypots from the ***Lively*** wreck on the Rowley Shoals along with the normal collection of cast iron objects such as cannon from a number of other sites. The rate at which the corrosion potentials changed with water depth was essentially the same for both wrought iron and cast iron and the Ecorr fell by 18.9 ± 1.5mv per metre. This behaviour was not expected on the basis of the previously understood model for corrosion of iron objects on wreck sites where the level of dissolved oxygen had been considered to be of paramount importance. Standard oceanographic data shows that the level of the dissolved oxygen generally increases slightly with water depth up to approximately 30 metres owing to the greater hydrostatic pressure. However, one parameter that does decrease most markedly with increasing water depth is the total amount of water movement. The movement depends on the combined action of the channelling effects of reefs and general topography of the sea bed. The full details of these observations have recently been reported (MacLeod, 1989) but the implications for the ***Sirius*** wreck site and its management are that we are now able to go back and look at the data on the ***Sirius*** site and see that the corrosion potential is being determined by the oxygen flux available to the corroding metal. The oxygen flux is in effect the nett supply of dissolved oxygen to the concreted corroding iron object. The supply rate is determined by diffusion parameters which include not only the level of dissolved oxygen but also the combined affects of water movement and localised turbulence and eddies caused by wave action etc.

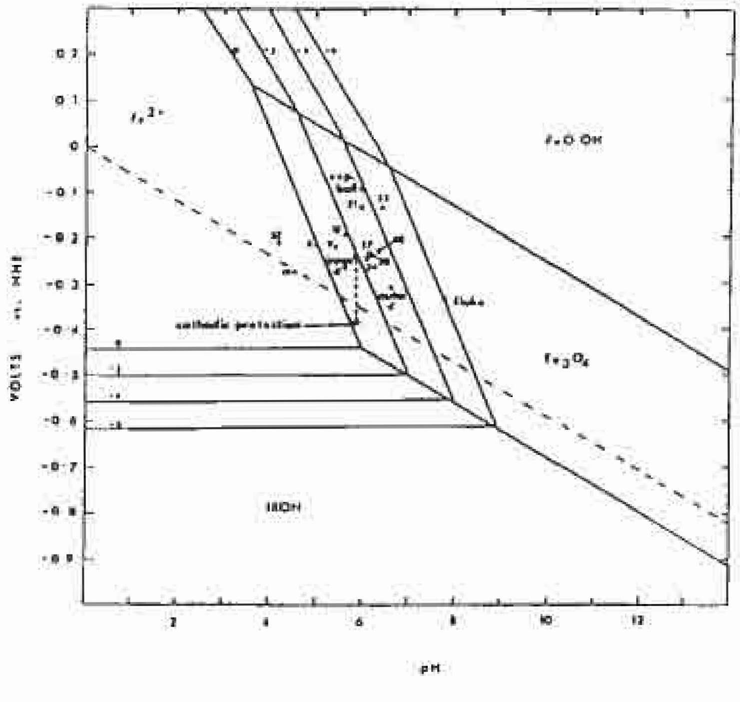


FIGURE 4 Pourbaix diagram for iron in seawater showing observed on-site values of surface pH and corrosion potentials for iron objects.

Site Management

Looking back at the data from the *Sirius* site it is now possible with this new corrosion model to see that the way in which the ballast lies on the site has a large bearing on its subsequent corrosion rate. If there are a number of similar objects on a site then consideration of the known topography and effective exposure of the objects in conjunction with a corrosion potential survey will make it possible to tell which objects are in the most corrosive environment and hence which are more likely to be extensively degraded. The results of the work can be applied in two ways: firstly the most "at risk" objects can be determined and appropriate strategies developed to ameliorate the accelerated degradation rate. Secondly, if sample material is to be recovered from the site then we have a better understanding of which objects are more likely to be in a less extensively corroded state and be easier to treat and should also have the greatest chance of retaining their archaeological values .

The development of the new corrosion model has been a most rewarding and unexpected result of the 1988 season of the corrosion potential measurements on the *Sirius* site. We now have a very powerful archaeological management tool at our disposal. It should be noted however that the interpretation of corrosion potential and pH measurements is something that is fraught with difficulty for they are dependent on a wide range of parameters. Interpretation of such measurements should not be entered into without assistance from appropriately experienced personnel. Recent work on cannon recovered from the wreck site of the ***Fairy Queen*** at North West Cape in Western Australia has shown conclusively that the corrosion potential measurement is in fact a cumulative index of the immediate past environment in which the object has been placed. On the basis of the water depth at which the cannon was recovered a prediction was made of the expected corrosion potential. However the observed value was significantly lower than that expected on the basis that of the water depth. The observed depth of graphitization (corrosion) was lower than that predicted solely on the basis of the water depth but it was higher than the value predicted on the basis of the observed corrosion potential measurement. This apparent conundrum was resolved when changes in the nature of the wreck site was considered. Coastal geomorphological and meteorological evidence has shown that major cyclonic activity results in massive movement of the sand in the area close to the shore. Thus the cannon had been alternatively buried for considerable periods and then exposed. This was further supported by the very nature of the iron corrosion products and the type of concretion formation which was a composite mixture of that expected for buried and exposed sites. The more negative corrosion potential observed on site was in fact a reflection of the immediate past burial since the cannon was measured only a few days after the cyclone had exposed it to the observation of the visiting diver. In the light of this observation a great deal of significance can be placed on the measurements from the *Sirius* site in that they relate not just to the prevailing oceanographic parameters on site at the time of measurements but they more accurately reflect the long term differences in micro-environment.

D) The oceanography of Norfolk Island and the *Sirius* wreck.

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Abstract

The report reviews both published and unpublished information on the oceanography of Norfolk Island and the HMS*Sirius* wreck site. The information is applied to a discussion of the events surrounding the wrecking of the ***Sirius*.**

Introduction

On 5 March 1790 HMS ***Sirius***, the flagship of the First Fleet, sailed from Sydney for Norfolk Island with '116 male and 67 female convicts, 27 children, and two companies of marines — 275 people in all' (Henderson and Stanbury, 1988). The idea was for these people to go to Norfolk Island to ease the strain on supplies at Sydney. After Norfolk the ship was to proceed to Canton for supplies for Sydney.

Norfolk was reached after 8 days and unloading of convicts completed by 15 March. Bad weather then forced the ship out to sea for several days. On 19 March conditions improved, the officer in charge of Norfolk, Philip Gidley King, signalled safe landing conditions for longboats, and Sirius moved in towards Kingston on the south coast of the Island. Regretably the SE wind swung to the south and strengthened and ***Sirius*** became embayed.

Despite manoeuvring and, finally, the dropping of an anchor, the ship drifted sternfirst onto a nearshore reef. No lives were lost. The ship completely broke up after 2 years. An inquiry found the cause of the wreck to be an unexpected westward current, combined with the wind shift.

Norfolk Island (29° 02'S, 167° 56'E) is an isolated island of volcanic origin on the Norfolk Ridge that runs from New Caledonia to New Zealand (Figure 1). The island vicinity has not been the subject of extensive oceanographic studies, although some information has been collected, often as part of other studies. It includes:

- Currents calculated from the drifts of ships.
- Sea surface temperature and salinity patterns determined from data collected by merchant ships in the Tasman and Coral Seas.
- Temperature and salinity measurements at a 50 m "coastal station" some ten miles south of Norfolk Island since 1977.
- Sea level data collected at Norfolk Island since 1969 as part of CSIRO's island and coastal tide gauge network.
- Studies of the Tasman Front.
- The paths of satellite-tracked drifters that have passed near Norfolk Island after having escaped from the eddies of the East Australian Current (EAC).
- Environmental information collected at two potential sites for an ocean sewerage outfall on Norfolk Island.
- The data collected as part of the "Scorpio" expedition along 28° S in 1967.
- The local knowledge of the people of Norfolk Island.

Part I of this report reviews the above with a view to better understanding the general oceanography of the Norfolk Island vicinity. Part II examines the environment at the wreck site of the HMS *Sirius* in October 1988. Part III examines the conditions on 19 March 1790, the day that the ship foundered.

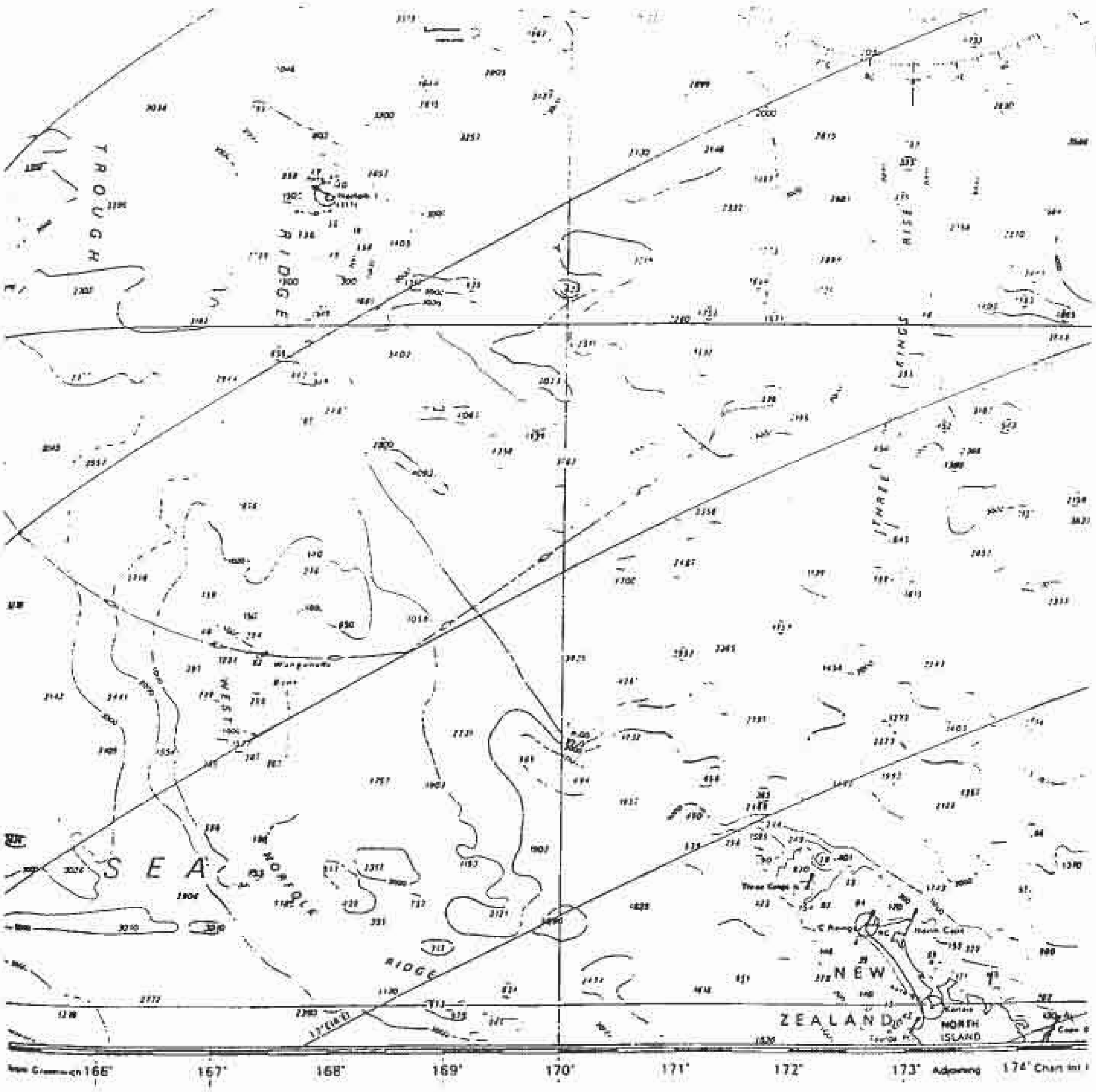

Figure 1 A chart of part of the Norfolk Ridge.

Part I: The oceanography of the Norfolk Island vicinity

Currents calculated from historical ship drift measurements

Monthly charts of current vectors (Figure 2) for June and December from Wyrtki (1960)) show Norfolk Island to lie at the Tropical Convergence formed between the westward-flowing waters of the Trade Drift and eastward flowing waters leaving the EAC system. The Convergence moves north and south during the year (Figure 3) in step with the movement of the southern boundary of the southeast trade winds. The movement of the Convergence means that from June to November the waters come to the Island from the WSW and from December to May they come from the NNE.

Temperature and salinity patterns from merchant ships in the Tasman and Coral Seas

The CSIRO Division of Fisheries and Oceanography used merchant vessels to monitor the surface temperature and salinity fields of the Tasman and Coral Seas from the mid-1960s to the late 1970s (Rochford, 1977; Edwards, 1979). At the peak of the programme, with up to 28 participating vessels, it was possible for monthly maps of temperature and salinity to be drawn. Ten-year averages for the months of June and December are given in Figure 4. Norfolk Island falls within the high salinity subtropical region described by Edwards as having an excess of evaporation over precipitation. The salinity is lower to the north, west and south due the effects of the tropics, the EAC, and low salinity sub-Antarctic surface water respectively. The maps do not reveal the Tropical Convergence, nor do they reveal the Tasman Front, which we will discuss later.

The Norfolk Island 50 m coastal station

The mean monthly values of temperature, salinity and nitrate for the period 1970-81 for the surface and 50 m depth are shown in Figure 5 (Edwards, pers. comm.). The mean surface temperature ranged from 18°C in August/September through to 24°C in March; the highest temperature was 26°C in March 1981. The 50 m temperatures suggested that there was a mixed layer from April to September and a shallow thermocline at other times. Salinity also showed an annual cycle , albeit with a small amplitude, ranging at the surface from a low of 35.7 in September to a high of a little over 35.8 in April. The 50 m salinities suggested that there was a mixed layer from March to September (and in January).

The nitrate variations at the surface were complicated, although there was a distinct spring maximum in September. The 50 m values showed a clearer annual cycle, being high from July to November and low at other times, except for January.

Comparing the coastal station 50 m salinities and nitrates with the annual current variations and movements of the Tropical Convergence in Figure 3 suggests that relatively high salinity, low nitrate waters come to the island from the NNE in the first half of the year, while relatively low salinity, high nitrate waters arrive from the WSW in the second half of the year. Figures 3 and 5 suggest that the waters north of the Tropical Convergence have temperatures in excess of 21°C.

The T-S plot , while revealing, perhaps, an anomalously low value for salinity at 50 m in February (the 40 m value was also low, while the shallower ones were not), shows an annual cycle of low temperatures and salinities in spring and high ones in late summer and autumn.

The Norfolk Island tide gauge

The tide gauge has been maintained on the pier at Kingston since 1969. The tides are semidiurnal and the range is roughly 1.4 m at the springs and 0.8 m at the neaps, flooding to the west for 5 hours and ebbing to the east for seven hours, in both cases at 1.5-3 knots (Australian Pilot, 1973). Hamon (1979) found that mean sea level for 1970-73, adjusted for the effects of atmospheric pressure, showed much less variance than that for Lord Howe Island. He attributed this to the influence of the EAC and its eddies extending to Lord Howe Island, but not to Norfolk Island. The data set had some gaps in 1970-72, but could be seen to show an annual variation of amplitude only 6 cm.

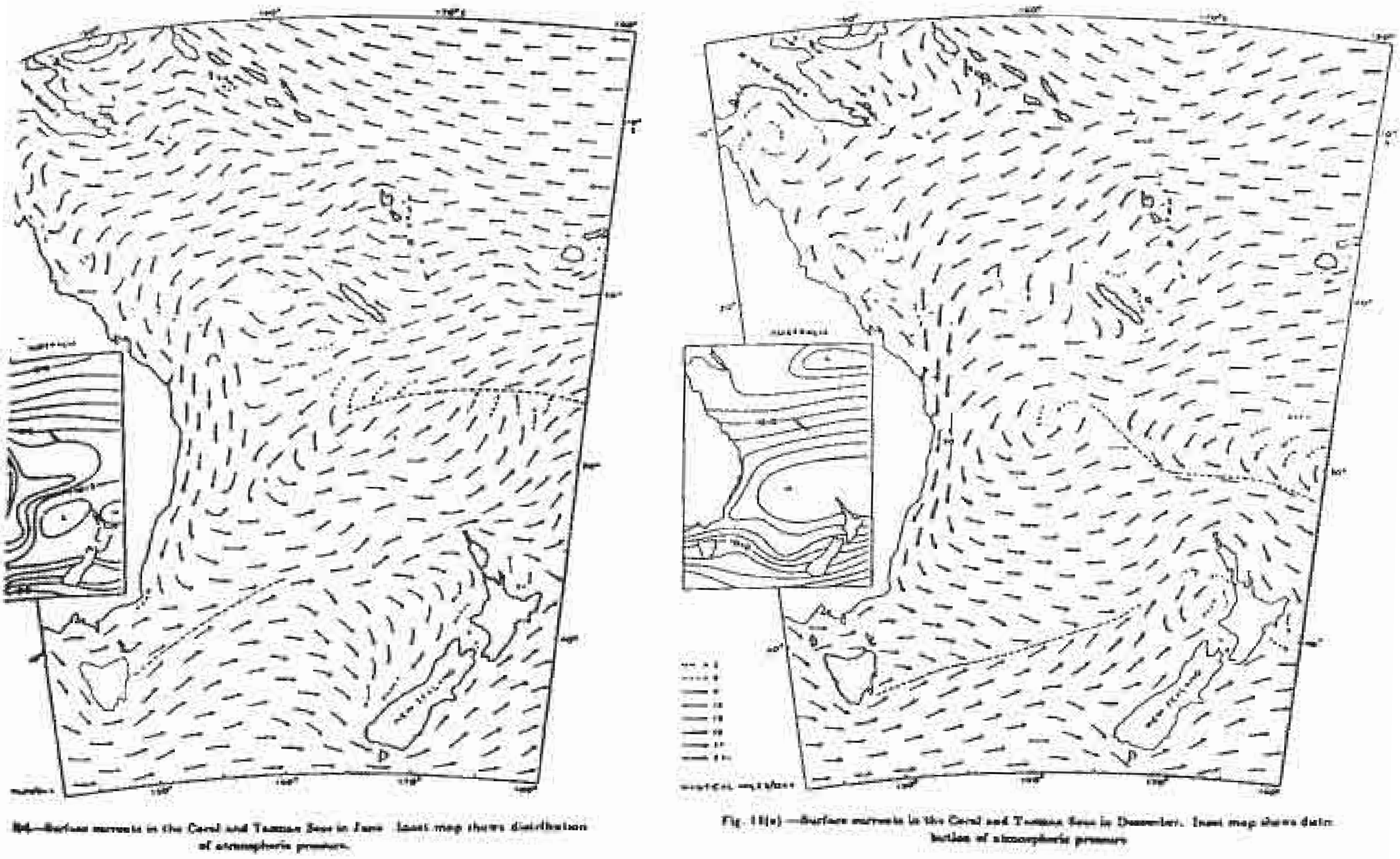

Figure 2 Surface currents in the Coral and Tasman Seas in June and December from ship drifts (inset shows the distribution of atmospheric pressure). From Wyrtki (1960).

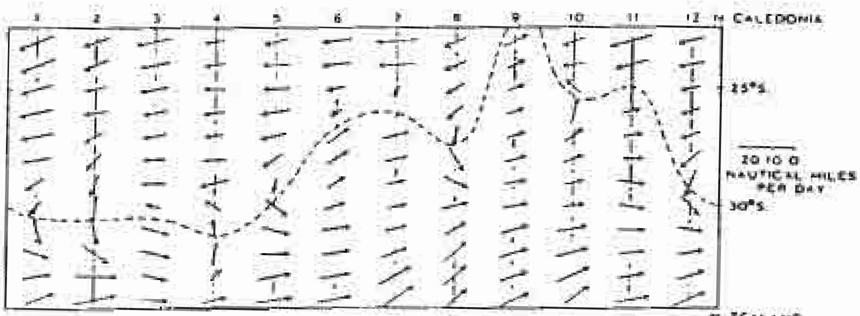

Figure 3 A latitude time series of the currents and the position of the Tropical Convergence determined from ship drifts (from Wyrtki, 1960). Norfolk Island is at 29° S.

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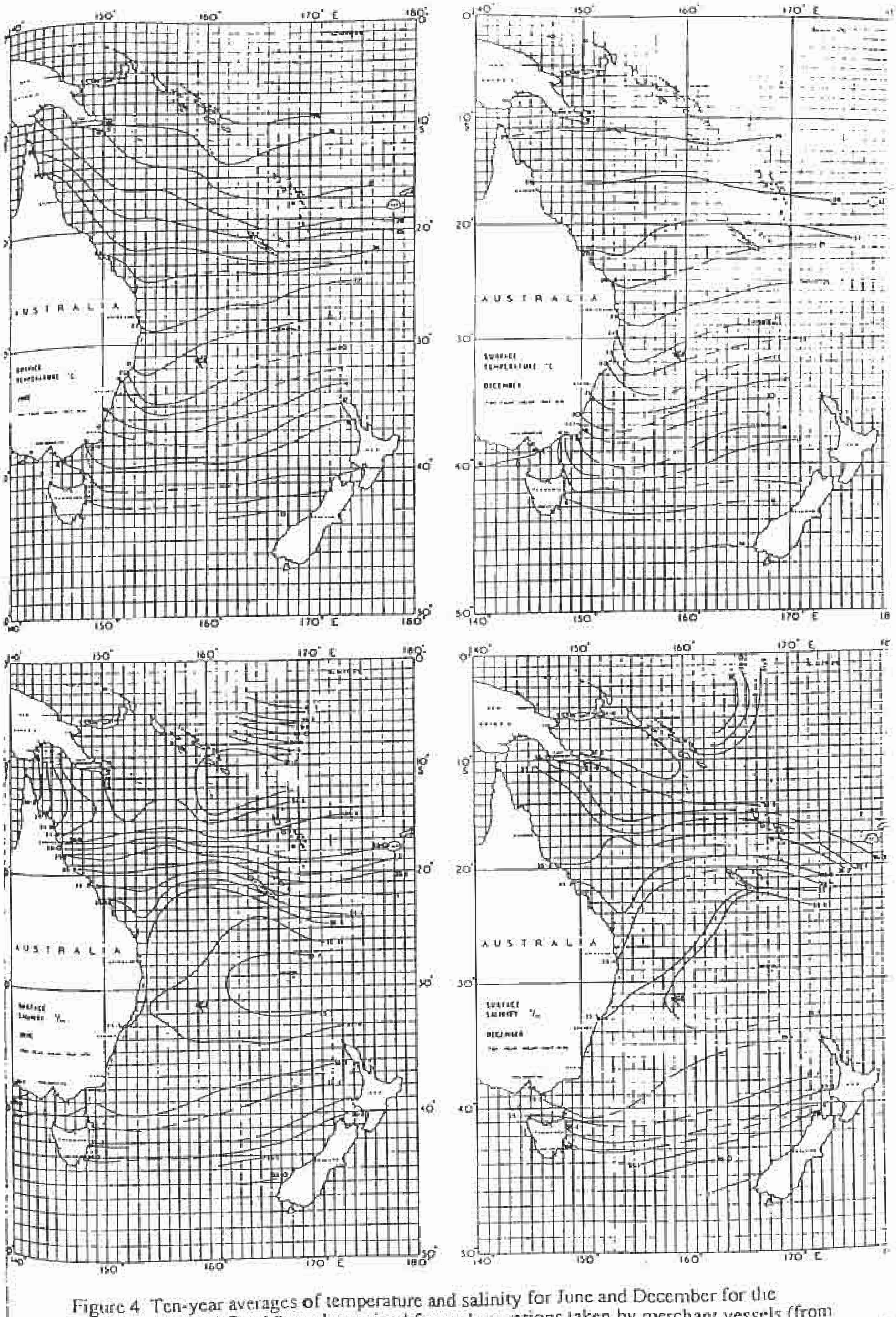


Figure 4 Ten-year averages of temperature and salinity for June and December for the Tasman and Coral Seas determined from observations taken by merchant vessels (from Edwards, 1979).

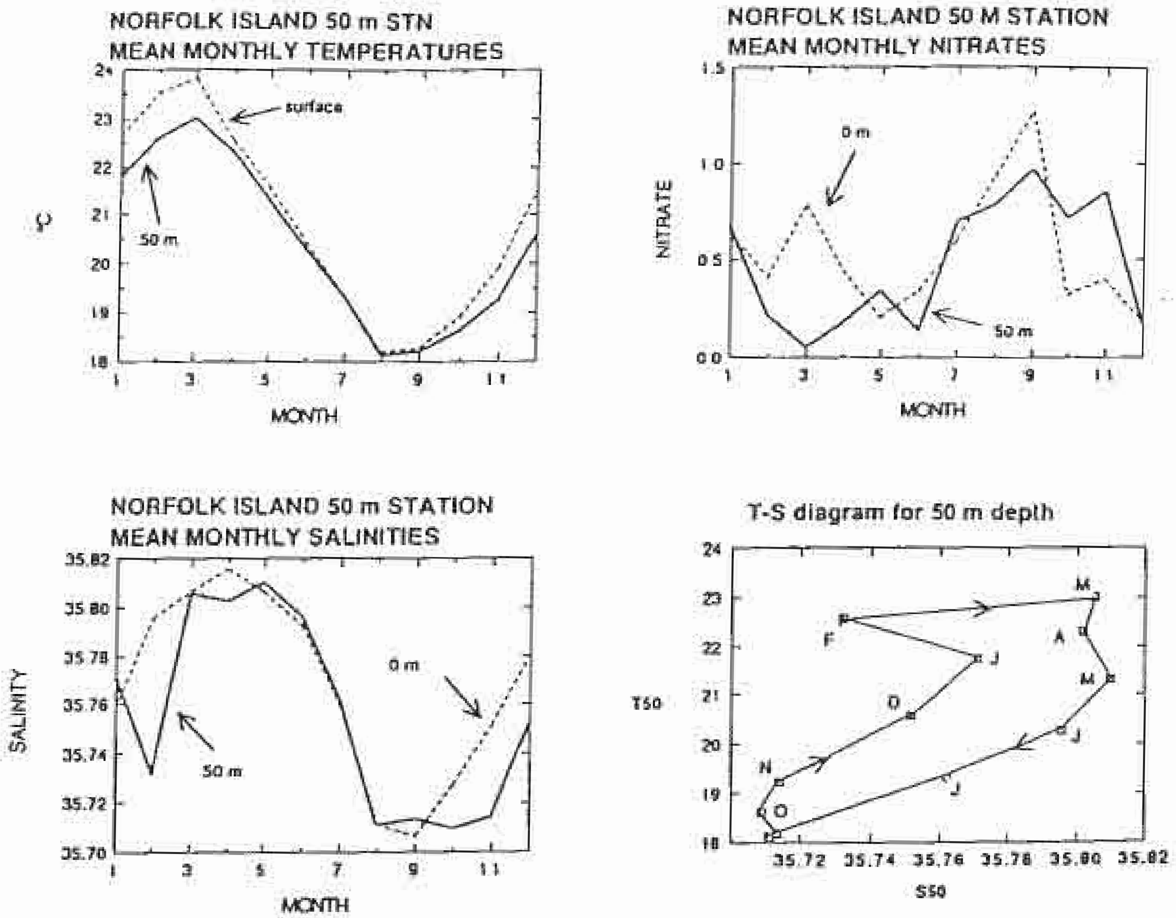


Figure 5 Mean monthly (1971-80) surface and 50 m depth data from the Norfolk Island coastal station. The annual cycles of temperature, salinity and nitrates are shown, along with the T-S diagram.

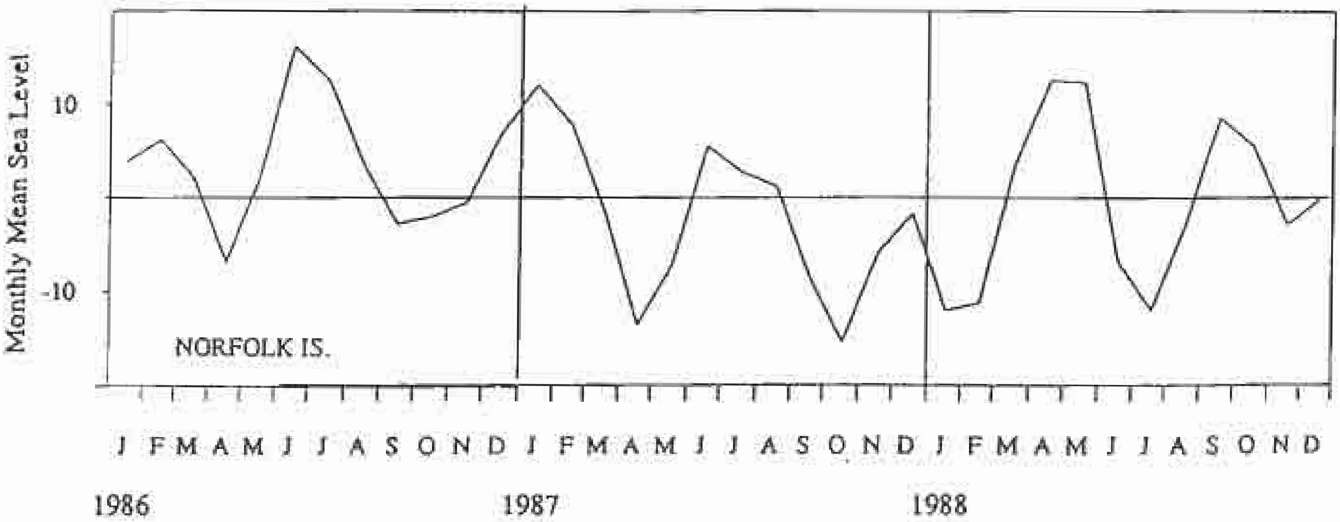


Figure 6 The tidal residuals for the Norfolk Island tide gauge for 1986, 1987 and 1988 (Ridgway, pers. comm.).

More recently Ridgway (1988, pers. comm.) pointed to a semi-annual variability in mean sea level: highs (+0.1 m) from December through February and June through August; and lows (-0.15 m) from March to May and September to October (Figure 6, in particular 1986 and 1987). Hamon's (1979) data for 1973 showed the same type of behaviour. The reason for this variation is not immediately obvious. It could be related to local wind forcing or to larger scale oceanographic influences bringing waters of higher steric height to the region. However, with its six-month period, it does not match the twelve-month period of the north-south movement of the Tropical Convergence (Figure 3).

It was after identifying the semi-annual variability above that the author and Ken Ridgway found that 1988 was an unusual year — the phase of the variability was reversed. This may be related to the warmer than usual sea surface temperatures that were measured. It may have relevance in the annual cycle of appearances and disappearances of different fish species. For example, local fishermen described how big pelagics such as tuna are around the island in January and February. In September-November smaller pelagics such as kingfish, trevally, smelt, Australian salmon, and also krill are found. This corresponded to the time when the bottom fish were not found in the region. The satellite-tracked drifter data that we will discuss later reveal that EAC waters probably reach the island in the January-February and September-November periods when the pelagics are found. If this is the case, then in 1988, an unusual year as we have seen, the timetables for the various fish species may have been askew.

Studies of the Tasman Front

Stanton (1976) summarized the knowledge on the Tasman Front (then called the Mid Tasman Convergence) that meanders west-east and is located to the south of Norfolk Island between 32° and 34°S. The Front is associated with a current jet of up to 0.65 ms^{-1} (Stanton, 1979), a surface temperature and salinity front, and forms a boundary between two subtropical surface water types. One is the direct outflow from the EAC and the other is the Tasman Current, which is a broad northwards flow offshore from the west coast of New Zealand and is the eastern part of a broad, anticyclonic gyral in the southern Tasman Sea. The temperature at the Front is centred on 17°C, with the average change across it being 1.6°C and the maximum 2.6°C. Changes in surface salinity of up to 0.16 have been measured. The Front was frequently observed in winter.

Given that the surface temperature at the Norfolk Island 50 m station does not fall below 18°C, it would appear that the Tasman Front always lies to the south of the island.

Since Stanton's work above, the Tasman Front has been examined through temperature measurements from ships, aircraft and satellites (Andrews *et al.*, 1980; Stanton, 1981; Mulhearn, 1987), although Mulhearn's work was confined to the western part of the Tasman Sea and excluded the Norfolk Island region. Andrews *et al.*, (1980) found that the Tasman Front meandered within a 600 km wide zonal band centred on 33° or 34° S and stretched from Australia to New Zealand.

Satellite-tracked drifters

Satellite-tracked drifters have been used in the waters east of Australia by CSIRO since 1972 (Cresswell and Legeckis, 1986). The paths of drifters that have passed near Norfolk Island are shown in Figure 7. The following comments can be made on them:

Drifter #2, 1972 moved northward along the western side of the Norfolk Trough in September and then crossed it in October. In November, some 100 miles north of Norfolk Island, it changed direction while over the Norfolk Ridge and then recrossed the Norfolk Trough, ultimately meandering its way towards Australia.

Drifter #1676, 1977 crossed the Norfolk Trough towards Norfolk Island in October and spent November wandering around within 100 miles of the Island. In December it moved off to the northwest to pick up the Trade Drift to the Australian coast.

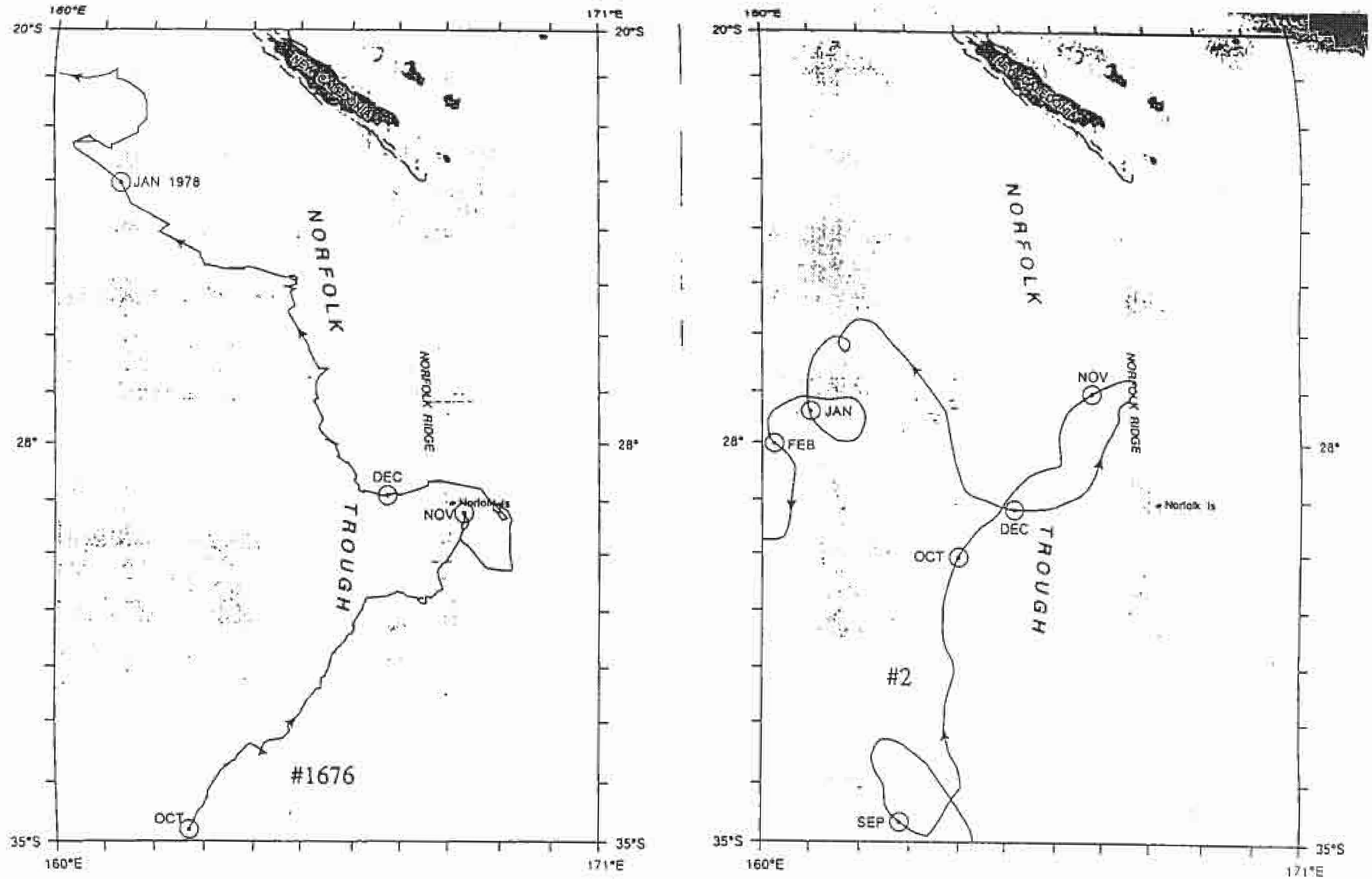
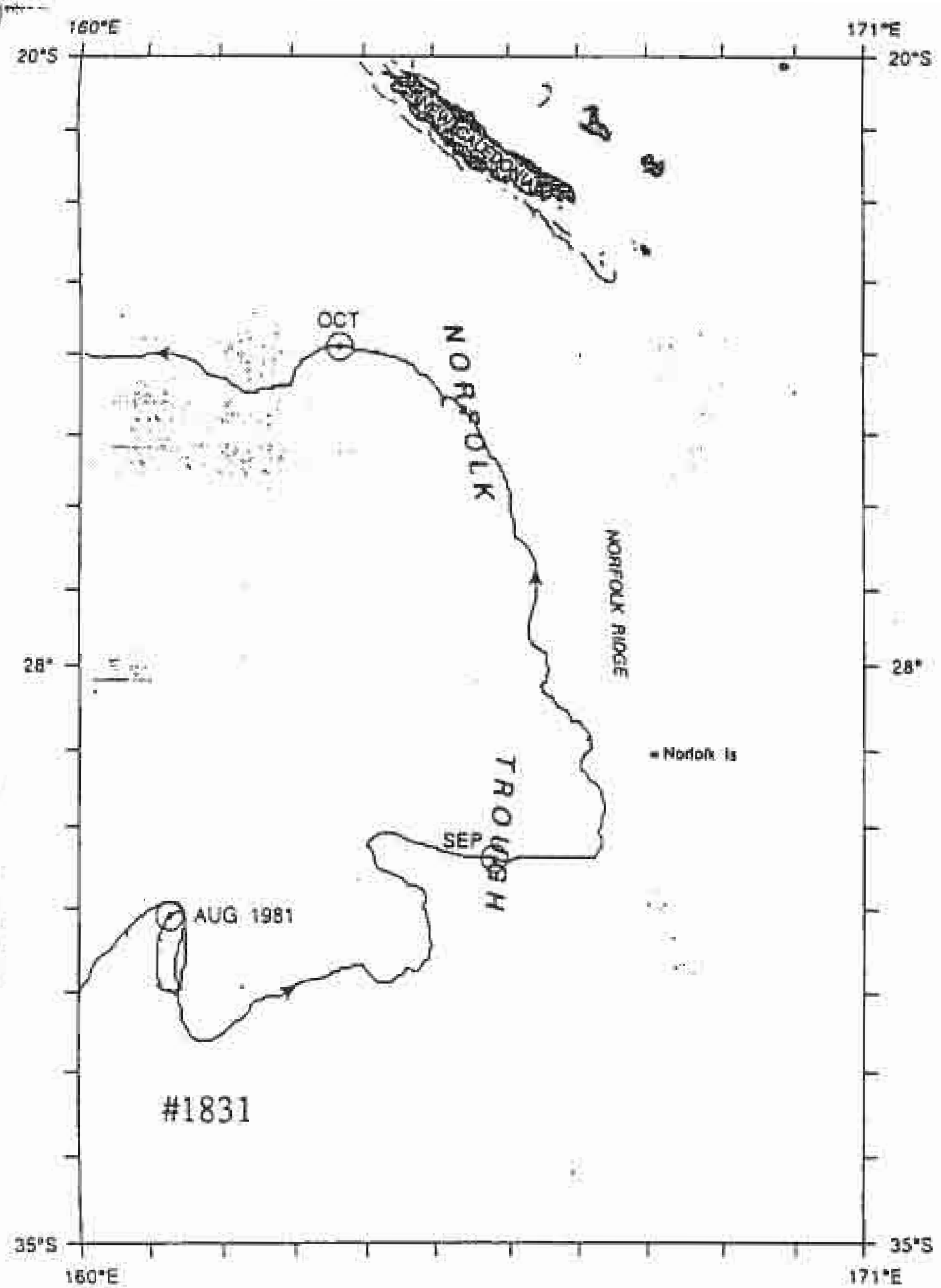


Figure 7 The paths of satellite drifters that passed near Norfolk Island between 1972 and 1986.



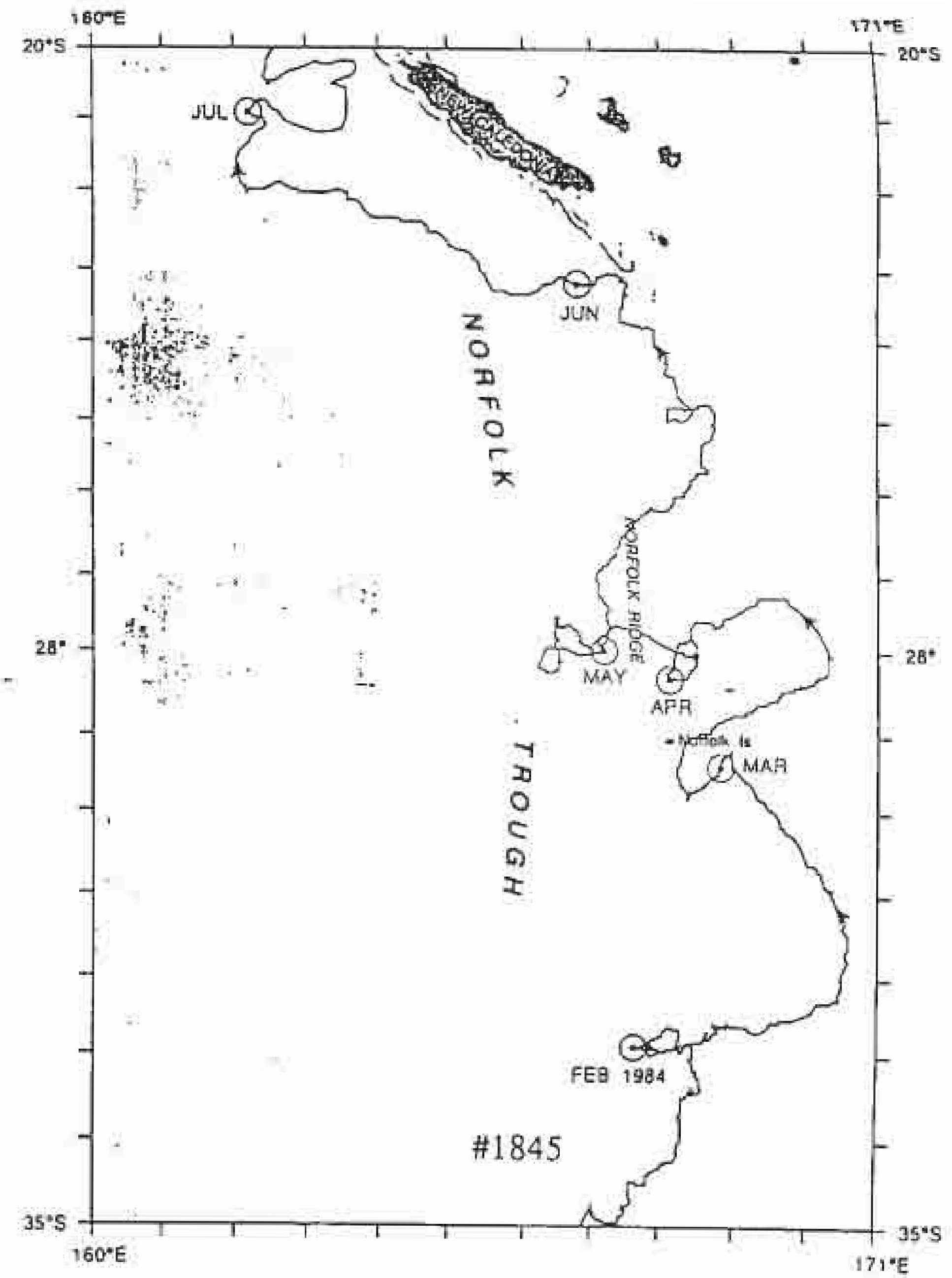


Figure 7 (continued)

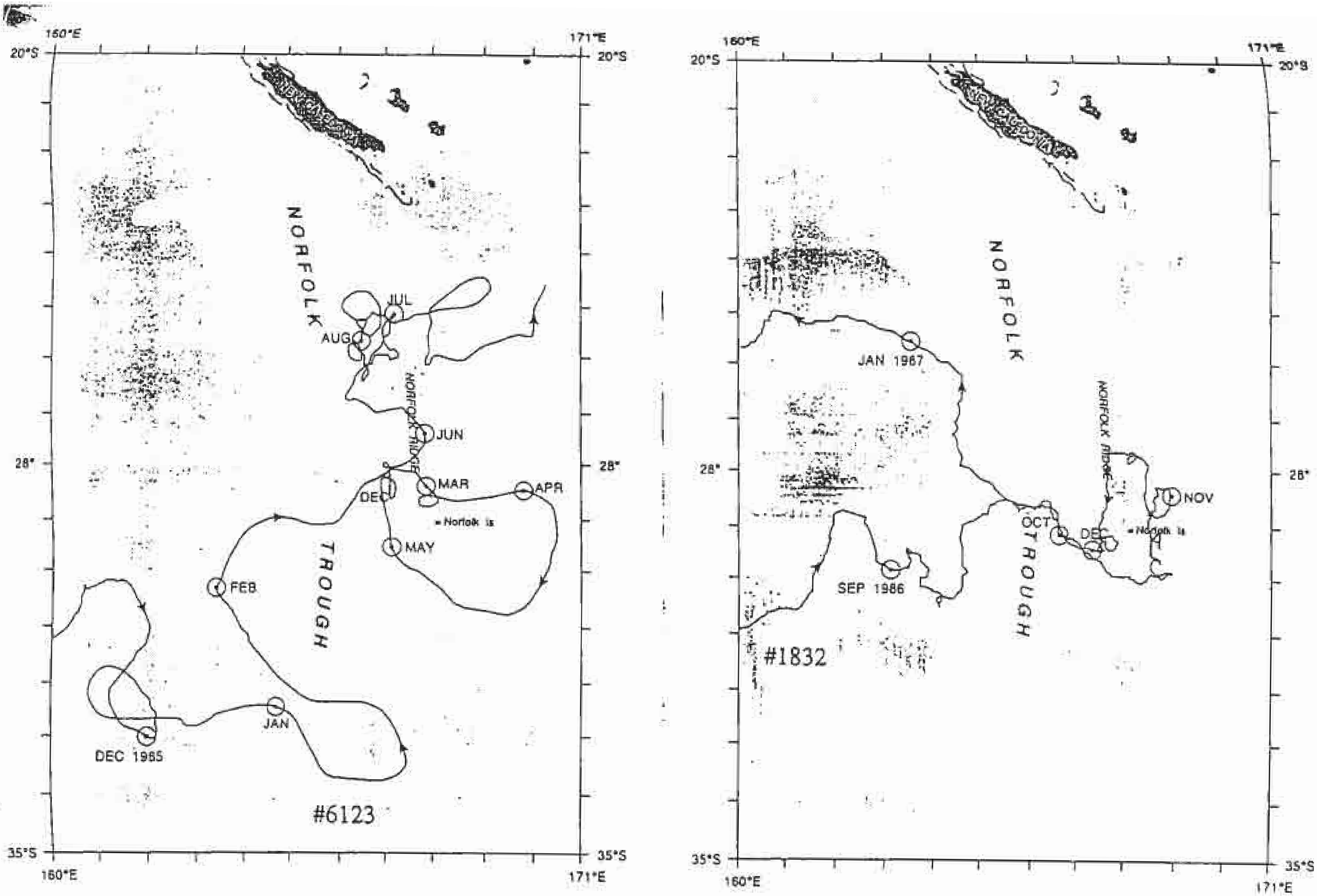


Figure 7 (continued)

Drifter #1831, 1981 moved across the Norfolk Trough in September and then parallel to the Norfolk Ridge passing 50 miles to the west of Norfolk Island. Its mean speed was around 0.4 ms^{-1}, with a maximum of 1 ms^{-1}. In October it crossed the Norfolk Trough going to the west along 24° S.

Drifter #1845, 1984 approached the Norfolk Ridge south of Norfolk Island from the southwest in late February rather than in September or October. It spent two months in the vicinity and then moved away to the northwest.

Drifter #1832, 1986 approached the Island from the west in September, having escaped from an EAC eddy. It looped clockwise around the Island in October and then moved off to the northwest.

Drifter #6123, 1986 approached the Island from the west in late February. It also looped anticlockwise around the Island before moving off to the north.

These data show that while "escapee" drifters from the EAC system usually found their way to the Island vicinity in September/October, two drifters did find their way there in February/March. This latter behaviour perhaps implies a short-term northward move of the Tropical Convergence that was not evident in the ship drift data analysed by Wyrtki (1960), but is hinted at by the low salinity values at the coastal station in February (Figure 5) . Note that after reaching the Island vicinity, all the drifters moved away to the northwest and north.

Environmental information collected at two potential sites for an ocean sewerage outfall on Norfolk Island

In April 1988 Aanderaa current meters were moored 3 m above the bottom in 11 m of water at Cascade and Headstone on the east and southwest sides of the Island (Consulting Environmental Engineers, 1988). Median speeds were 0.05 and 0.055 ms^{-1} respectively, with the tidal excursions being only 1-2 km. Drogues that were released moved at speeds of 0.12-0.18 ms^{-1} and 0.10-0.15 ms^{-1} at Cascade and Headstone respectively. Overall, the data suggested northward flow past the Island.

The "Scorpio" expedition from South America to Australia along 28° S in June/July1967

This expedition passed from east to west some 60 miles north of the Island occupying standard hydrographic stations (Stommel *et al.*, 1973). The Norfolk Ridge reached up to 1000 m at 28° S and the data showed a local salinity maximum of over 35.7 in the upper 100 m; it extended over several degrees of longitude. The associated temperatures were 19-20° C. These salinities and temperatures are in accord with those from the historical merchant ship observations (Figure 4) and the Norfolk Island 50 m coastal station for June/July (Figure 5). Between 800 and 1200 m was a salinity minimum of <34.5 in which the temperatures ranged from 4-6° C.

Part II: The environment at the HMS *Sirius* wreck site in October 1988

The site

The wreck site (Figure 8) extends onshore/offshore some 70 m as a very gently sloping plane in which there are several gullies and holes about several metres wide and one metre deep. The bottom is hard calcareous rock with a light covering of weed and numerous sea urchins. The depth across the site at mid-tide was measured with graduated poles and leadlines and found to range from 1.5 m onshore to 2 m offshore (Figure 9). For the next 60 m offshore the bottom falls away quickly at 1:20 to 5 m. This steep slope would allow many waves to reach the near-flat plane of the wreck site before steepening enough to break. Waves roughly 1.5 m high break at the inshore end of the site at mid-tide. This breaking wave zone spreads offshore

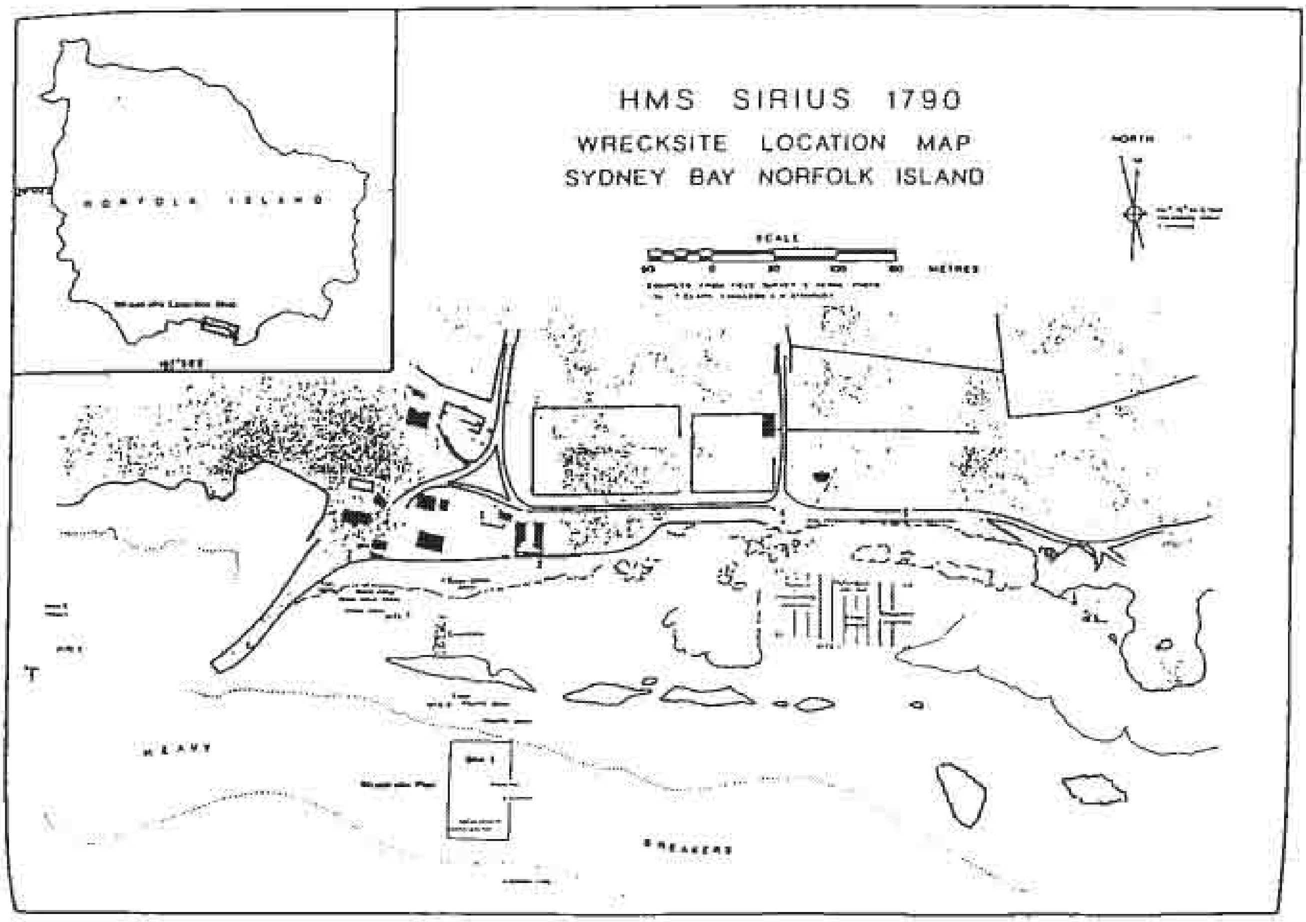


Figure 8 The wreck site of the *Sirius* (from Henderson and Stanbury, 1988).

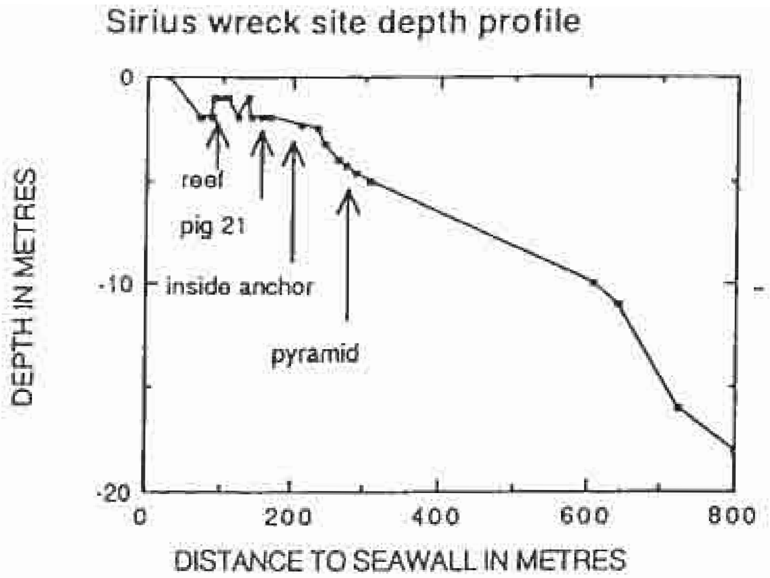


Figure 9 The depth profile through the wreck site. The pyramid is a concrete marker deployed during the October 1988 expedition.

as the waves increase in height and/or as the tide falls, because, roughly speaking, a wave will break when its height is equal to the water depth.

Waves

The background in this section was assembled from Van Dorn (1974), Silvester (1974), and Barber (1969). In it we take a knot to be 0.5 ms^{-1} and we take the acceleration due to gravity, g, to be 10 ms^{-2}. Both of these are accurate to a few percent.

The speed of waves, C, in shallow waters is related principally to water depth, d, and gravity, g, through

$$C = (gd)^{1/2} \ ms^{-1} \qquad (1)$$

In the open ocean, where the water is too deep for the waves to be retarded by the bottom, the wave speed is a function only of wave period, T, and can be expressed very nearly as

$$C = 1.5T \ ms^{-1} \qquad (2)$$

where T is in seconds. Thus the longest period waves generated by a storm propagate the fastest.

The wavelength is CT, or

$$L = 1.5T^2 \ m \qquad (3)$$

The longest waves to reach the ***Sirius*** site during October 1988 (Figure 10) had period 15 seconds and would have travelled in the deep ocean from a distant storm at 22.5 ms^{-1}, or 45 knots, with wavelength 340 m. At the offshore end of the wreck site, however, where their velocity would have decreased to 5 ms^{-1}, or 10 knots, their wavelength would have been 75 m.

The energy of waves in the open ocean is not carried at the phase speed, C, given by (2), but at the group speed, C_g, which is C/2. The effect can be observed when running with a set of waves in a boat. Whatever wave one is riding, when this wave reaches the front of the set it disappears, and so, in turn, will the following waves. In this way the set, or group, of waves progresses across the ocean at half the speed of the individual waves. In shallow water the energy is transferred at the speed of the individual waves, given by (1).

The significant wave heights (defined as the average height of the largest one third of the waves) for the month were estimated from the shore to range from 0.5 to 4 m (Figure 10) The two days having high waves were quite different: the first, 11 October, with 12 second, 3 m waves occurred with low winds and so was due to a distant storm. The second, 18 October, with 15 second, 4 m waves occurred with an onshore gale and so perhaps the Island was near the downwind end of the fetch.

At the crest of a breaking wave the velocity is

$$U = (g(0.75H + d))^{1/2} \ ms^{-1} \qquad (4)$$

where H is wave height.

Taking the 4 m waves of 18 October and assuming a water depth of 3 m at the moment of breaking gives the horizontal velocity at the crest to be near 8 ms^{-1}. During its subsequent plummet of 4 m, the water from the crest will acquire a vertical velocity component of almost 9 ms^{-1}. The resultant of these two components is 12 ms^{-1} (24 knots) at an angle a little steeper than 45°.

A notable feature of working on the ***Sirius*** site was the reciprocating motion associated with passing waves that easily overcame the efforts of divers to hang on and to work. From Silvester we find the shallow water oscillatory speed to reach offshore and onshore maxima of

$$|u| = (H/2)(g/d)^{1/2} \text{ ms}^{-1} \quad (5)$$

In other words, half the wave height times its shallow water speed.

The maximum horizontal displacements offshore and onshore are

$$|x| = (HT/12)(g/d)^{1/2} \text{ m} \quad (6)$$

Just beyond the limit of the ability of a diver to work on the site we might have the situation of a 2 m wave of 15 s period in 2 m depth. The corresponding maximum velocities due to the passage of the wave are 2.2 ms^{-1} (over 4 knots) outwards and then inwards; the displacements would range from 5.5 m offshore from the work station to 5.5 m inshore of it.).

Quite a different situation is that of divers being struck by the turbulent water at the front of a broken wave. This will be carried shoreward at the shallow water wave speed given by (1) and so could well be 10 knots.

The energy per unit area of the sea surface due to waves of height H is

$$E = \{g(H^2/8)\} \text{Joule m}^{-2} \quad (7)$$

where r, the water density is about 1000 kg m^{-3}.

The power of waves is given by

$$P = EC_g \text{ watts m}^{-1} \quad (8)$$

Multiplying the energy per unit area by wave group velocity, C_g, gives the rate at which this energy is transferred and, for example, enables the wave power reaching a coast to be calculated.

On 18 October E would have been 2×10^4 Jm^{-2} and P 225 kw m^{-1}.

Sea temperature measurements from the Kingston Pier

Sea temperature measurements were taken with a mercury thermometer supported by a small float so that the bulb depth was roughly 25 cm. Measurements taken twice during the day for the first ten days showed that the near-surface waters warmed by as much as 1.5° C in the afternoons (Figure 11). The measurements were interrupted for a week while a broken thermometer was being replaced.

Satellite infrared images

Although the satellite reception facility at Hobart has been operating for several years, there has, until this time, been no reason to process images from the Norfolk Island region. An image obtained on 4 October 1988 during the ***Sirius*** Expedition (Figure 12) shows a large part of the Tasman Sea to have been unusually cloud-free. The EAC separated from the central-north NSW coast and ran eastward along 34° S. Norfolk Island is in the centre of a southward flowing stream of warm water (21-22° C and coloured yellow in the image) which bifurcates near 30° S. This may explain why the October 1988 temperatures and the sea level (Figure 13) were unusually high. The 50 m coastal station sea surface temperature for 10 October was also high, viz. 21.5° C, as was the temperature at 10 m recorded by the current meter, which will be discussed later. From Figure 5a it can be seen that the mean temperature for October is 19° C, which is the temperature of the water (coloured green in the image) outside the warm water stream in the satellite image.

Using Stanton's definition that the Tasman Front is centred on 17° C means that it is marked in this image by the boundary between the green and light blue colouring.

Earlier in this report it was concluded that the waters north of the Tropical Convergence were warmer than 21°C — in other words, yellow with a red tinge in the image. The Convergence is convoluted with excursions southward at 159°E, 162°E (with a branch then off to the southeast) and towards Norfolk Island at 167°E .

The sea level record for October 1988

The observed and predicted sea level and the filtered and unfiltered tidal residuals are given in Figure 13. The times of large waves — 11th, 17th and 21st (Figure 10) — were also times of sea levels elevated by 10 to 15 cm. The tidal data will be discussed further with the current data below.

The current meter record

The current meter was moored 3 m above the bottom at the 13 m contour in a direct line 200 m out from the Kingston Pier from 8-27 October. It was an Aanderaa meter with a Savonius rotor, which, although not ideal because it responds to the oscillatory motions from waves, provided considerable useful information. Figure 14 shows the pressure, temperature, and the u (north-south) and v (east-west) components of velocity measured by the instrument each 15 minutes. The estimated significant wave heights from Figure 10 have been added to the diagram.

The pressure signal shows the influence of tides, with springs around the 11th and 25th and neaps at the 18th. Note that, while the mean depth appears correct, the range from 10 to 13 m is twice the real range (see the tidal record of Figure 13); the instrument is not suitable for sea level measurements.

The pressure signal also shows, as noise, the influence of the large waves on the 11th, 17th and 20th/22nd. The noise is obvious in both the velocity components. In fact, wave noise is apparent whenever the significant wave height exceeded 1.5 m. These periods can be seen to have been associated with enhanced flows to the southeast. The wave noise is more obvious in the v component of the current record. It is this component, with the WNW-ESE coastline, that is likely to contain wave noise transmitted to the meter through the onshore-offshore fluctuations in the direction of the vane. Both components will, of course, contain noise in the form of an increase in the apparent speed from the rectifying effect of the Savonius rotor on the oscillatory motion due to the waves. On the other hand, the total rotor revolutions do give an indication of the flow of water past the meter due to all causes.

The progressive vector diagram (Figure 15) shows that each time the wave heights were small there was weak flow to the west upon which were superimposed tidal current reversals. During the large wave periods the reversals were overwhelmed by the ESE current.

Taken together, the current, wave and sea level data suggest that on days when the waves were smaller than about 1.5 m there was weak flow to the west, upon which were superimposed tidal current reversals with speeds of a little over 0.5 knot.

On those days when large waves (from swell or local storm) broke into Sydney Bay the sea level was elevated by 10 to 15 cm and this drove a current of up to 1 knot ESE parallel to the bottom topography. Twice per day there were brief tidal pulses to the west.

The tide gauge data from 1986-1988 (Figure 6) show occasions when sea level rose by as much as 40 cm. Whether or not these translated into strong SSE currents is not known.

On a shorter time scale, the alongshore current component (ie. that along the WNW-ESE alignment of the progressive vector diagram) and the overlay of predicted tides (Figure 16) suggest that Sydney Bay contains an eddy that is spun up by the tide. A flood tide flowing to the west outside the Bay induces clockwise flow in the Bay; an ebb tide flowing to the east outside the Bay induces anticlockwise flow in the Bay.

What this means is that inside the Bay, probably within 1 km of the shore, the present data set reveal a back-to-front situation: the tide should flood in from the east, but, because of the eddy that is set up, it appears to flood in from the west.

The temperature record from the current meter showed a ramp increase between the 9th and the 21st, then a decrease of 0.5°C, followed by a gradual increase. The record showed solar heating on most days to lead to a warming of 0.5°C; this was followed by cooling at night. Some of the unusual shapes in the trace are probably due to the combined effects of advection and vertical temperature structure.

The drogues that were released near the pier and floats moored at the wreck site will not be discussed in detail in this report, save to say that they confirmed the picture presented above.

Part III: The conditions that prevailed on 19 March 1790

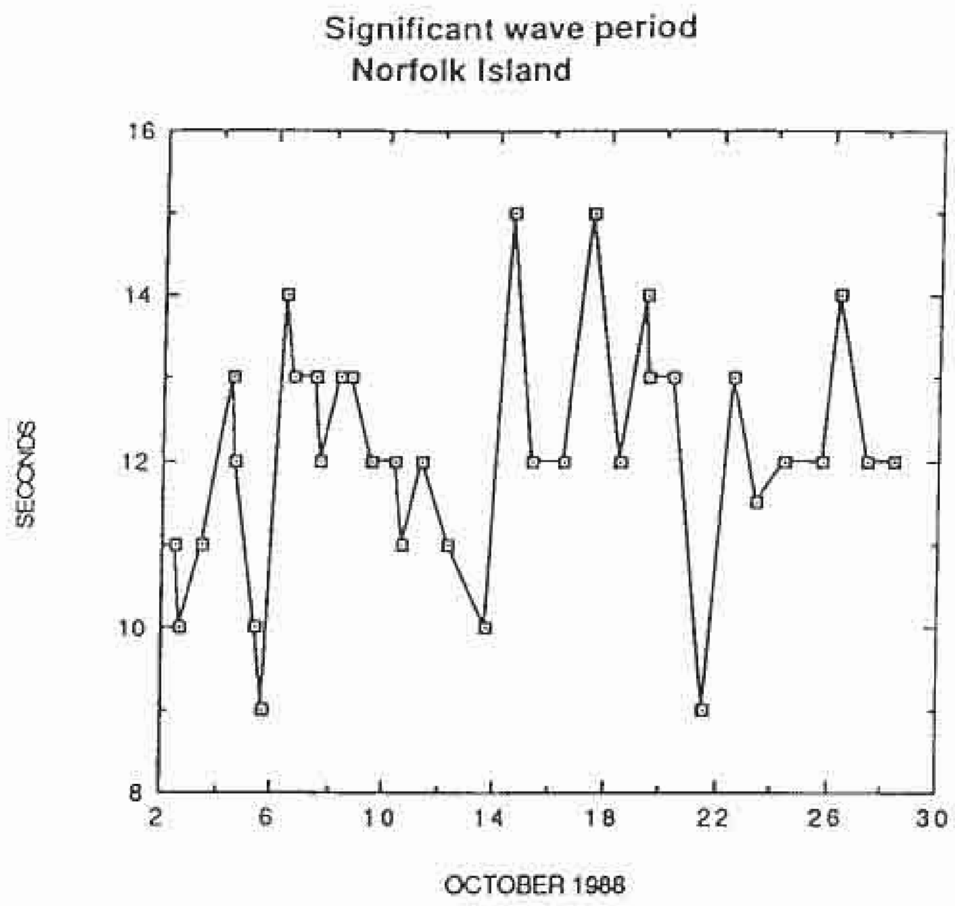
The various logs — Hunter's, King's, Bradley's and, not least of all, Seaman Nagle's — make rich reading and the temptation to quote them at length is almost overwhelming. For example, from Nagle:

> we got a boat along side and sent Capt Cooks time peace and two wimen, one being pregnant, on shore. They ware wives to two of the musicioners. They got safe ashore. The Capt ordered the masts to be cut away. By cutting the lanyards of the larboard rigging, and the surf rolling aboard of us, the masts all went together. When the wimen on shore saw the mast go, they set up such cries and shrieks and hollowing that the Govenor had to send soldiers to drive them off the beach and compel them to remain in their huts."

However, I will confine myself to times, tides, currents and waves and leave the interested reader to peruse the logs. Here I draw together the observations from the logs, looking for both agreements and contradictions, and make comments, where relevant, based on the 1988 data:

Contemporary observers give the time of the wreck as around noon: King says 'at noon', Bradley says 'about noon', Hunter says 'about eleven' and Nagle says 1230 hours. I am not sure if the convention for time was the same as now, namely Greenwich plus 11 1/2 hrs.

The tide heights at different times during the day were noted by several of the log keepers and they generally agree with Ridgway's hindcast (Figure 17). For example, Bradley says that it was two hours ebb or eastern tide at the time that the first boat was loaded. According to Nagle this would be at about 1100 hours. Ridgway's hindcast shows that 1100 was, in fact, high tide. Bradley went on to note that later that day there was '1/2 flood & night coming on'.



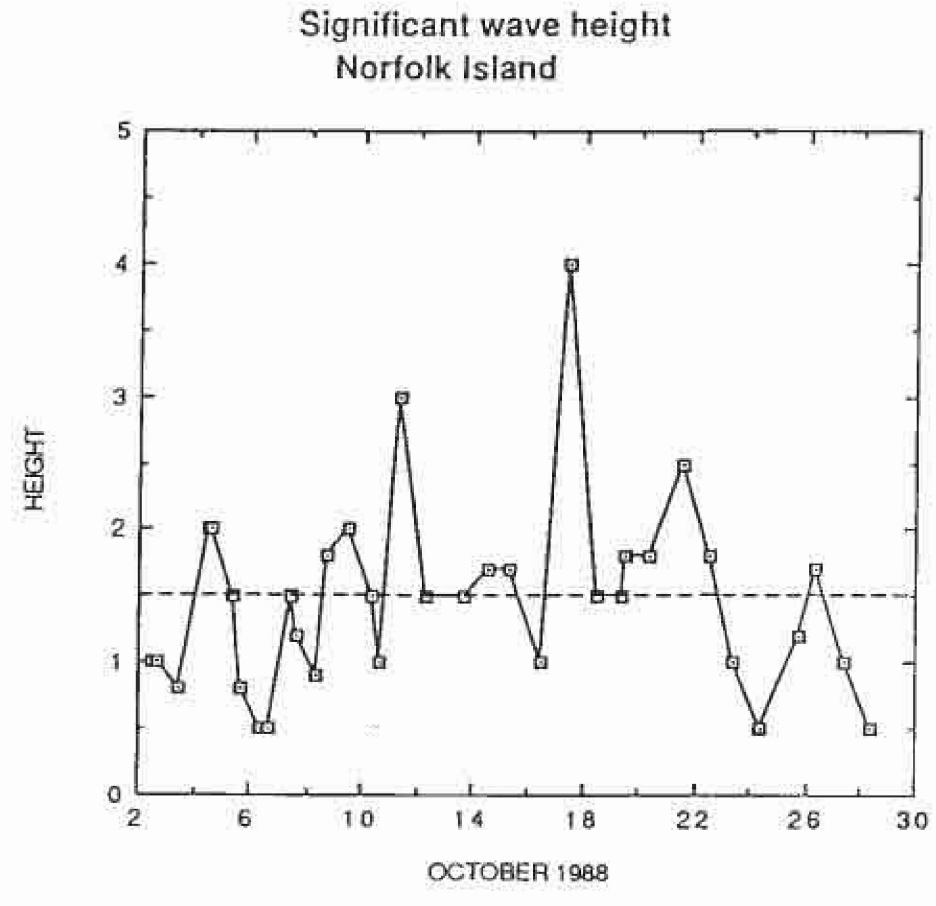


Figure 10 Significant wave periods and heights at the wreck site estimated from the shore during October 1988. The dashed line at 1.5 m wave height was felt to be a threshhold for diving at mid-tide.

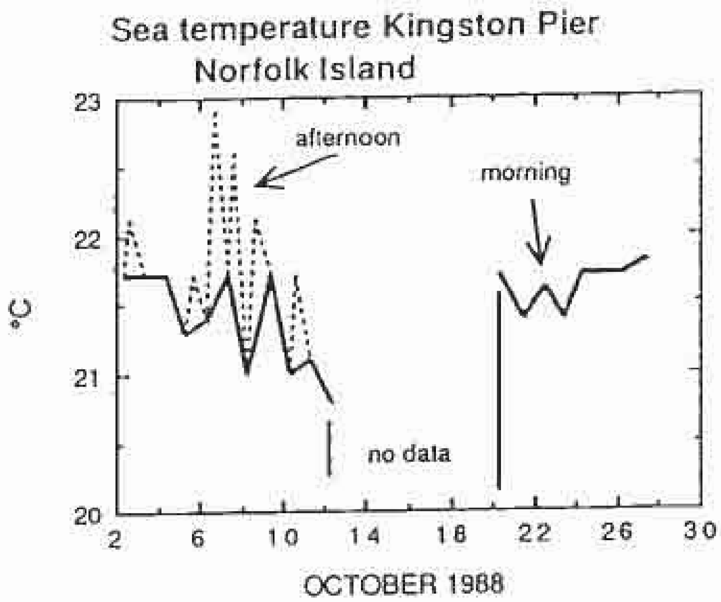


Figure 11 Sea temperature measured at the Kingston Pier with a mercury thermometer during October 1988.

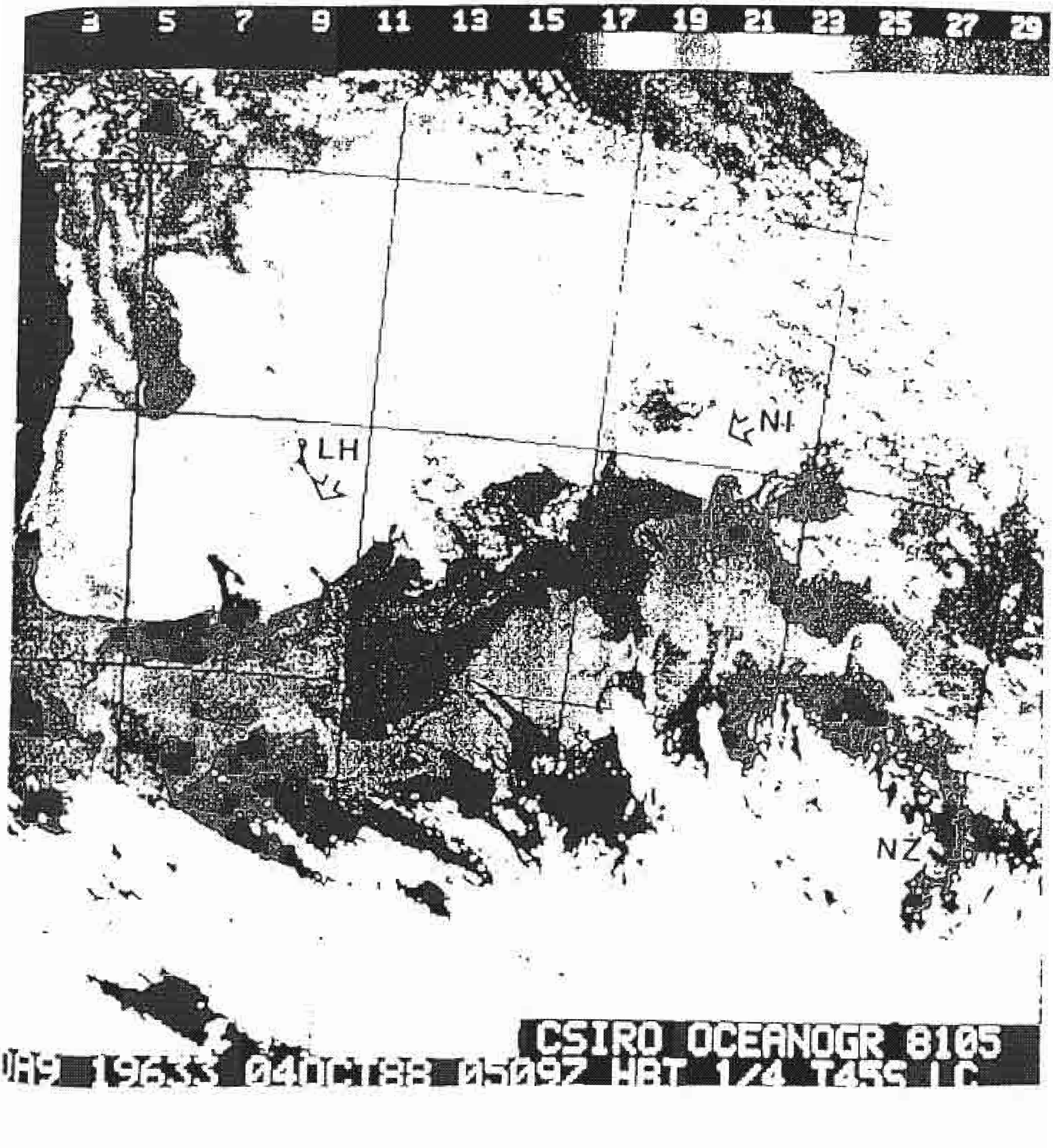


Figure 12 A NOAA satellite infrared image of a large part of the Tasman and Coral Seas. New Zealand (NZ), Norfolk Island (NI) and Lord Howe Island (LH) are identified; Australia is the brick red shape in the western part of the image. The colour scale for temperature is given at the top. Clouds appear white or, in some places, blue/green; large cloud bands can be seen across the bottom and in the top right of the image. The lat-long grid is 5° x 5°.

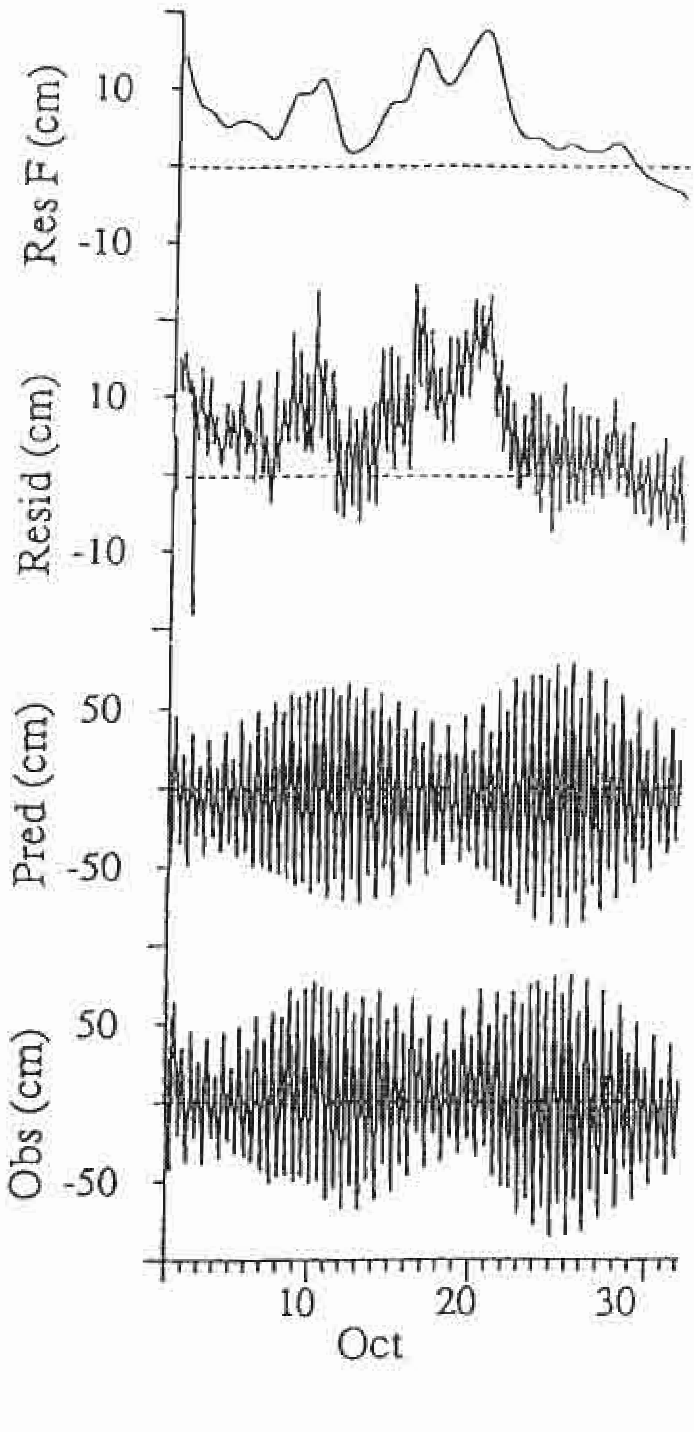


Figure 13 The observed and predicted sea level and the filtered and unfiltered tidal residuals. The times of large waves — 11th, 17th and 21st (Figure 10) — were also times of sea levels elevated by 10 to 15 cm.

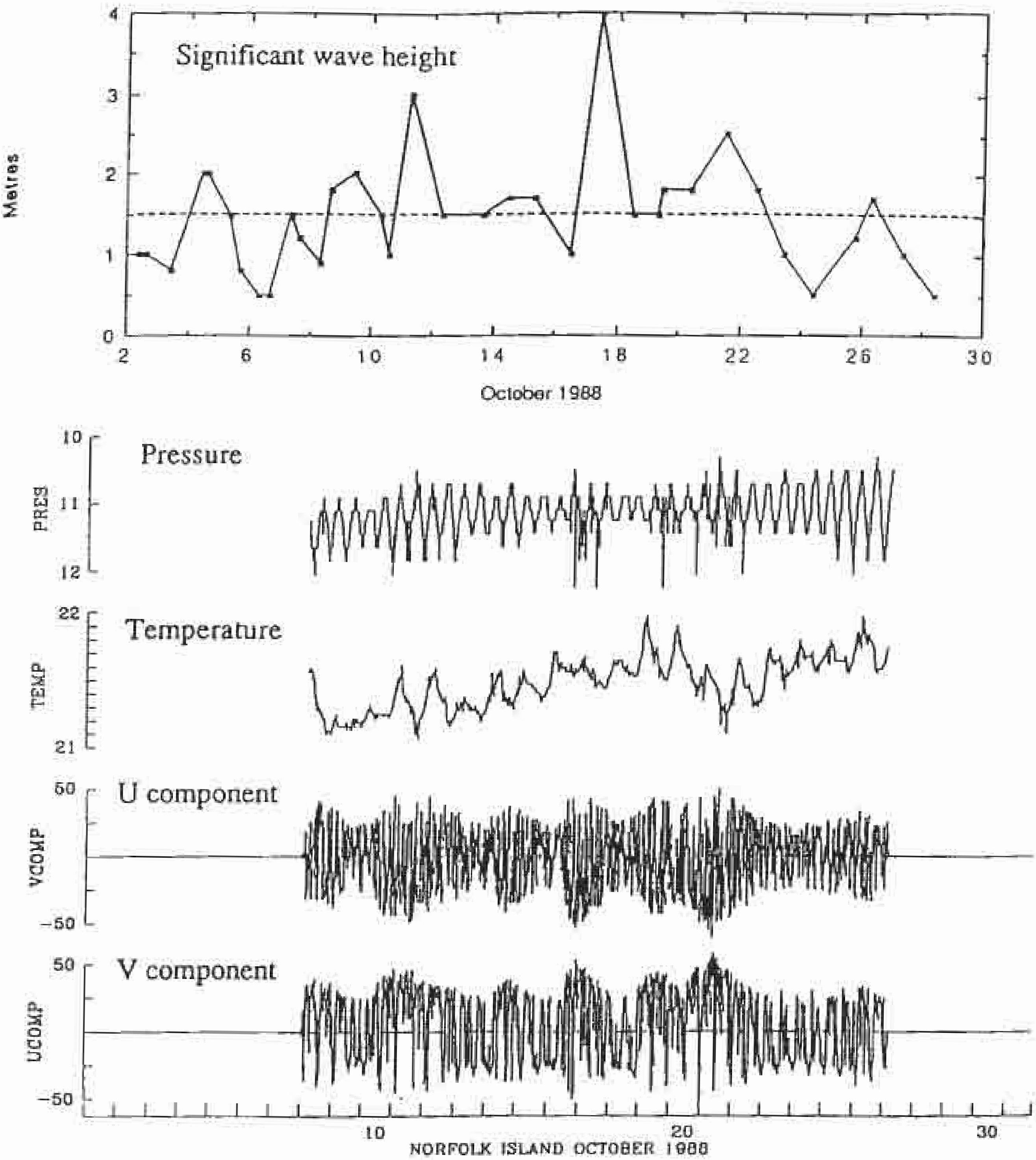


Figure 14 The pressure, temperature, u (east-west) and v (north-south) velocity components recorded by the current meter in October 1988. The significant wave heights from Figure 10 have been appended to the top of this diagram.

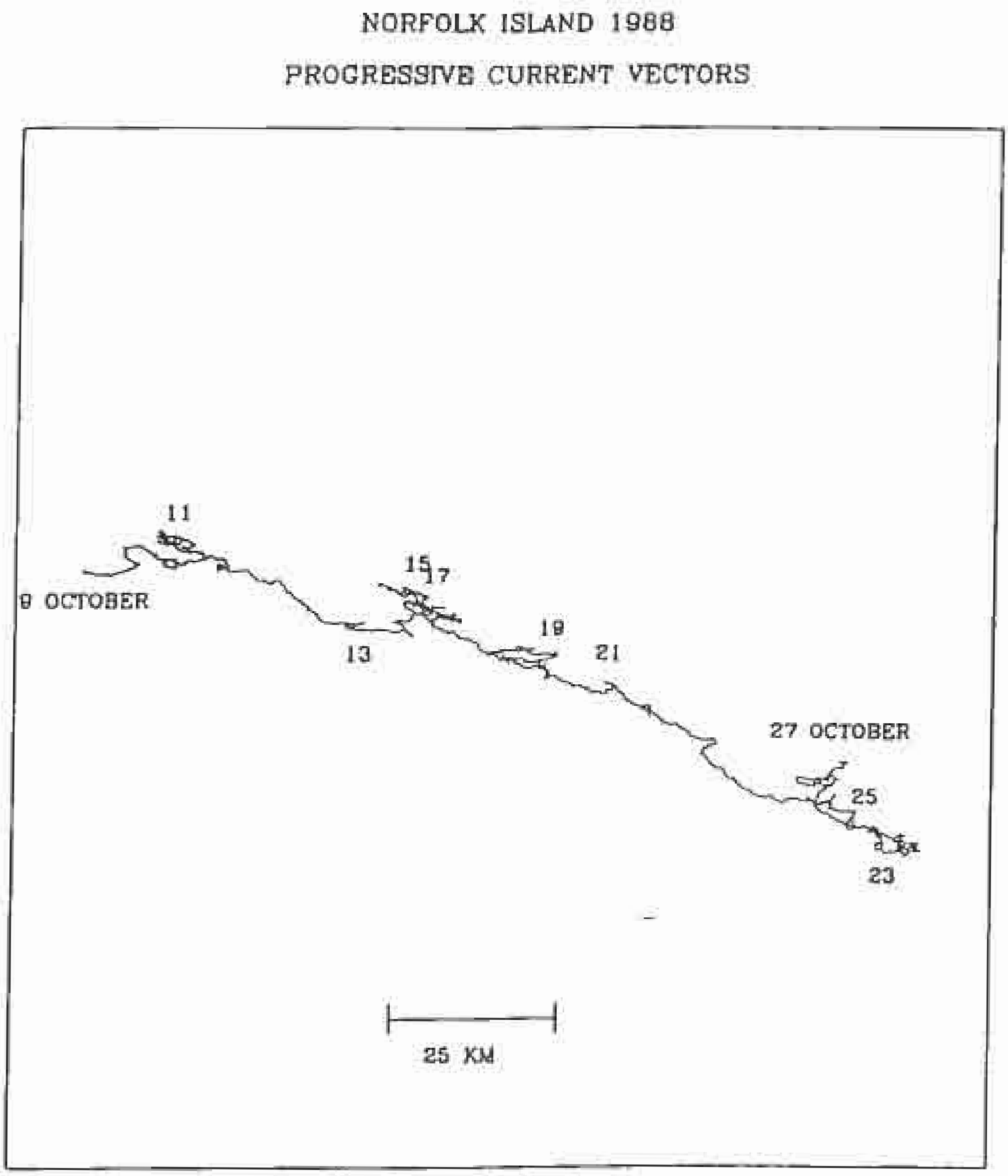


Figure 15 The progressive vector diagram from the current meter record. North is to the top of the page and the record starts at the left.

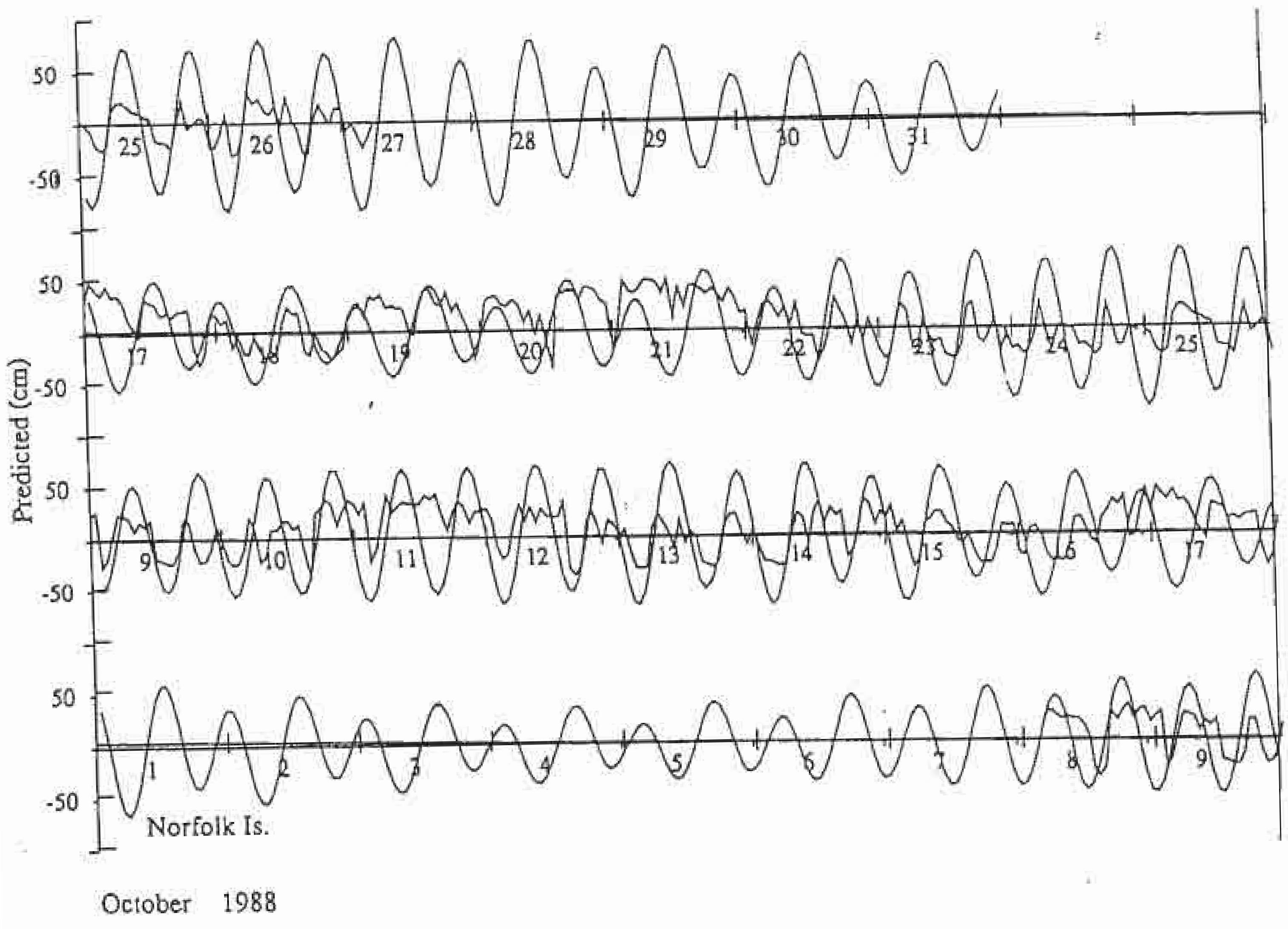


Figure 16 The alongshore current component from the current meter record and (transparent

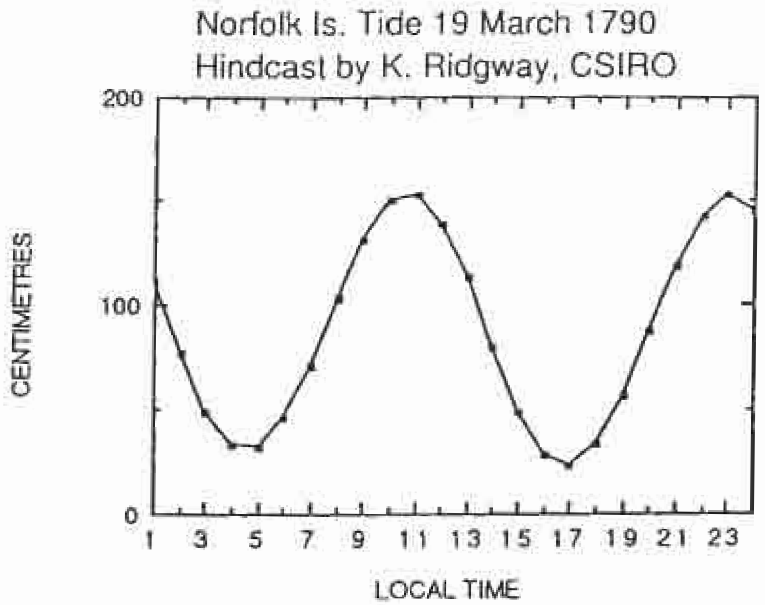


Figure 17..The hindcast for the tide height at Norfolk Island for 19 March 1790, the day that Sirius was wrecked (Hindcast by Ken Ridgway of CSIRO).

King also spoke of a 'flowing tide' in the evening. Both these observations agree with the low water hindcast at 1700 hours. During the morning after the wrecking Bradley reported, '...the surf still very high & the tide rose too much for those on the reef to work before all the people could be removed from the Ship.' Ridgway's hindcast suggests low water at about 0600 on that morning.

There is agreement that the **current** was atypically ('never met with before') and consistently westward, except for two hours that were not specified. Hunter and Ball (the latter in Bradley's log) said this. Bradley, in fact, said that it was believed the usual situation was for the ebb to set eastward for 9 hours and the flood to set westward for 3 hours. Hunter was relying on the eastward set to keep him away from the rocks at Pt. Ross at the western end of Sydney Bay.

Seaman Nagle said that the current was 'verry strong' to the west for 6 hours and then east for 3 hours (with 3 hours unaccounted for). At the time of the wreck he reported a strong current setting to the westward that carried their jetsam out to sea or into 'the whirlpool'. He spoke of this **whirlpool** later on when he was swimming with a message in a bottle: 'I new the danger I was in, the current very strong, setting in for the whirlpool, which was not more than 400 yards farther to the westward'.

The whirlpool may have been at the reef at which the pier now terminates.

In Part II we saw that the October 1988 current meter data pointed to an eddy in Sydney Bay that gave currents opposite to the floods and ebbs expected farther offshore. The raised sea level from large waves drove a current to the SSE that almost masked the effects of the tides. When the waves were small there was very weak overall flow to the west upon which was superimposed the oscillatory tidal signal. It appears then that the 19 March 1790 situation, with predominate westward flow, was quite different to that encountered in October 1988. The reasons for this may lie in the fact that the seasons were different, or that different years may be different. As we have seen, 1988 was unusually warm and the background currents may have been unusual.

The major contradiction concerns the **wind**, with the Officers' logs contrasting with Nagle's: According to Bradley, in the early morning the gale moderated. This was similarly reported by King as, 'Moderate gales at daylight' and that he made 'the Signal that Landing was very good ' Later, when the ship was manoeuvring to avoid Pt. Ross (between 1200 and 1230 hours from Nagle's log), the wind, according to Bradley, shifted 2 points to the south.

The contradiction comes with Nagle's observations of the conditions:

> Having a fine pleasant day with a light breeze offshore, all the seamen that could muster hoks and lines was ketching groopers, not thinking of any danger...we ware two close in, the swell of the surf having holt of us though it did not brake...we made sail that we could set, and a light breeze offshore, but it all availed nothing. The swell was stronger than the wind, and the swell still driving us in...we struck."

Nagle's observations of what appeared to be an onshore current associated with the **waves** is interesting, but it just opens up more questions: was the flow (to the east?) inside the lagoon drawing water across the reef, since it was high tide? Was the ship being given a slight nudge shoreward by the passing of each wave 'though it did not brake?'

Certainly, that afternoon, on a falling tide, probably with broken water moving shoreward, a barrel with a line attached was floated ashore and then a hawser was attached to a pine tree so that people could be suspended from a pulley and hauled ashore. Nagle describes the waves:

> Four men could sit on the grating at one time, but when they ware halling them to the reef, they would be under water a considerable time, when the surf was rolling in over them to a great highth.

Conclusions

Standing on the abrupt cliffs of Norfolk Island watching the waves and the strong tidal rips gives a mariner the feeling of being on a ship in the middle of the ocean. This report has brought together previous oceanographic observations from the island vicinity and it has reported on some new ones. As much as possible this oceanographic information has been incorporated into discussing the events surrounding the wrecking of the ***Sirius.***

E) Testing a Systemic Model of a Shipwreck on the *Sirius* wreck site.

Gaye Nayton, Postgraduate Student, Archaeology Department, University of Western Australia, Nedlands.

In 1979 Keith Muckelroy proposed the concept that a shipwreck can be seen as a system. This concept had evolved out of work he was doing on British wreck sites, particularly the ***Kennemerland*** site, but Muckelroy sought to expand on this base to produce a general model that would be applicable to all wreck sites.

Muckelroy identified a series of processes which were involved between the intact ship and the observed sea bed distribution of artefacts from that ship. These processes and their relationships to each other were presented within a systemic framework by using a flow diagram (Fig 1).

Muckelroy's concept is a potentially important one for maritime archaeology. Most wreck sites suffer scattering to some degree and many have no coherent ship remains within which to interpret this scattering. In this situation, interpretation is impossible unless the processes which produced the observed distribution are understood. Without this understanding hypotheses concerning ship structure, layout or social organization are not possible and interpretation is reduced to the identification and listing of artefacts.

Although Muckelroy's model was proposed in 1979 little subsequent research appears to have been carried out to test its viability. Use has been made of the model as a general framework of explanation (for example Keith and Simmons, 1985) yet the model itself has not been rigorously tested.

As part of the requirements for a BSc (Hons) degree Muckelroy's model was tested against a case study. Research aims were to:

a) Test the validity of Muckelroy's concept that a shipwreck can profitably be viewed as a system.

b) Test the viability of the model by examining whether the processes involved can be successfully identified and their effects measured.

c) Test Muckelroy's claim that his model is general and can be applied to all shipwrecks.

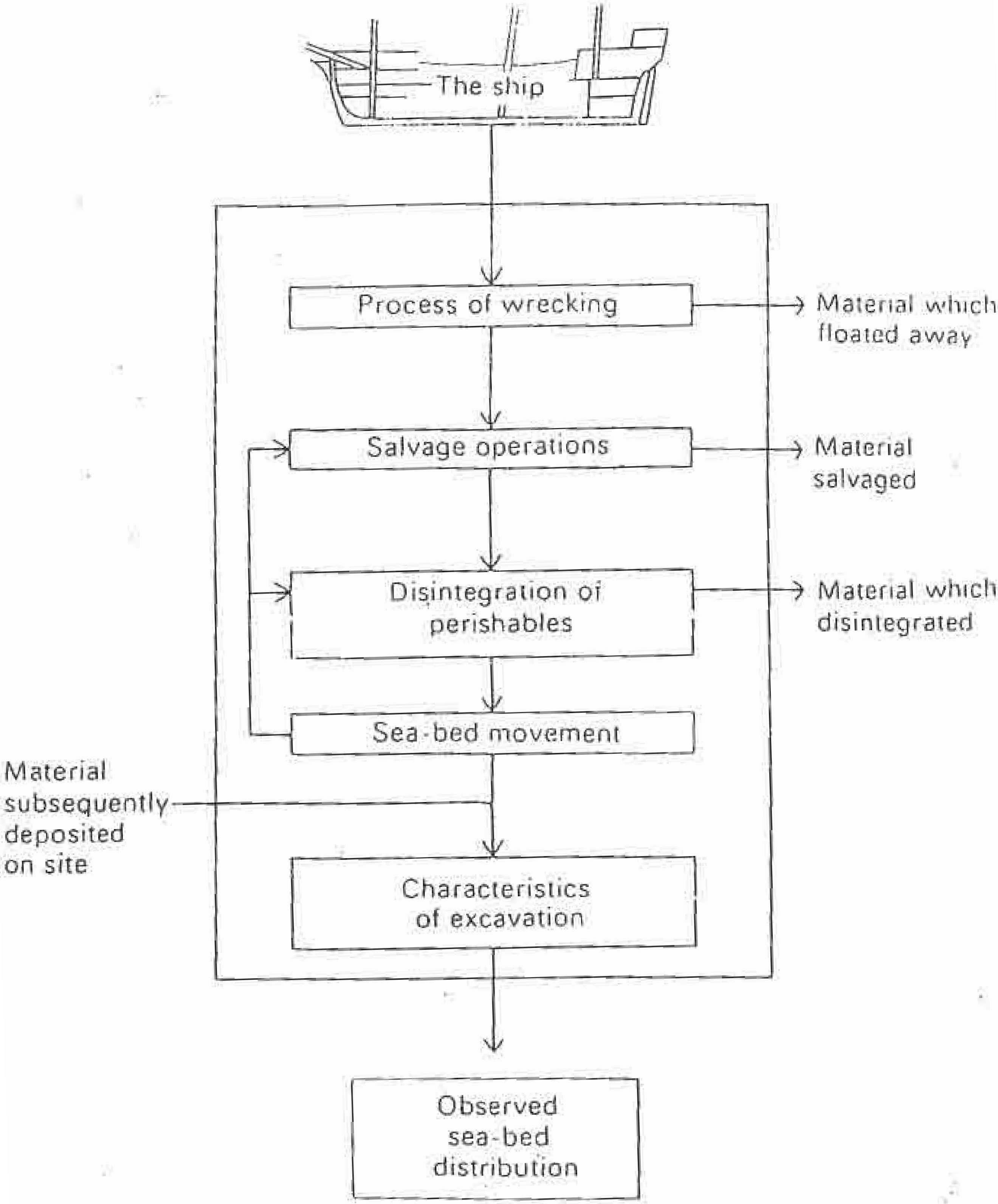
The shipwreck chosen to test the model against was HMS ***Sirius,*** which has been the subject of on going research since 1984 (Henderson, 1984., Henderson & Stanbury, 1985., Henderson & Stanbury, 1987). The ***Sirius*** is situated on a near shore coral reef within the surf zone. This is an extreme environment quite unlike the wreck sites Muckelroy was working with. As such the wreck provided a good test of the model's generality.

Methodology was to establish the historical background information on the site first then to approach each factor in Muckelroy's model separately in an order which facilitated interpretation. This was not the order in which they appear in Muckelroy's flow diagram (Fig 1). Current research on the processes involved in each factor was established and this knowledge was applied to the site. Each factor was assessed for how well it could be applied to the site and additional factors necessary to apply the model were sought and assessed.

Historical Background

HMS.***Sirius*** was built on the Thames in 1780 as the merchant ship ***Berwick*** . It was purchased while still on the stocks by the Royal Navy for use as an armed transport, as it was a roomy vessel of 511 tons. It was re-commissioned and fitted out as a naval 6th rate of 20 guns

FLOW DIAGRAM OF A SHIPWRECK.



Muckelroy, 1979:158.

for the First Fleet voyage. At Port Jackson the **Sirius**, being the largest of the two ships left with the colonists, served as both warship and supply ship..

In 1790 the vessel was wrecked in Sydney Bay, Norfolk Island while delivering supplies to the settlement of Kingston. Norfolk Island is a small island in the Pacific Ocean between New South Wales and New Zealand which was settled soon after initial settlement on the mainland.

Sydney Bay is located on the southern side of the island. It is a dangerous harbour fringed with reefs. On the western side of the bay reefs associated with Point Ross extend offshore, while the passage between Point Hunter and Nepean Island on the eastern side of the bay is also dangerous. In the bay itself, a coral reef extends parallel to the shore. This has two small passages through which ships' boats can reach shore (ships themselves cannot approach land). These passages are often unusable due to heavy surf conditions over the reef.

There are six surviving eye witness accounts of the shipwreck (Bradley,1790, Clark,1790, Fowell,1790, Hunter,1793, King,1790, Nagle,n.d.). These were used in the following summary of events.

On 5 March 1790 the ***Sirius*** and the *Supply* sailed from Port Jackson to Norfolk Island. They arrived on the 13th, but were driven away from the island by unfavourable winds until 19 March. Arriving after the ***Supply,*** Captain Hunter sailed the *Sirius* as close to shore as he thought safe before unloading. He did not anchor, but relied on the ebb tide to stop the ship drifting onto the rocks off Point Ross. However, a strong western current pushed both ships towards Point Ross and they had to make sail. The ***Supply*** tacked successfully out of danger but a sudden wind shift prevented the ***Sirius*** from doing the same. Hunter was forced to take a starboard tack which left him sailing parallel to the shore in an attempt to sail out of the bay by passing between Point Hunter and Nepean Island.

Before Point Hunter could be reached however, the combination of onshore winds and heavy swell pushed the vessel too close to the reef and Hunter was forced to turn into the wind in an attempt to sail clear. This was unsuccessful and the ship lost power. The small bower anchor was dropped but the vessel struck the reef stern first before the anchor cable could check it.

After striking, the ship turned broadside to the surf. The masts were cut down in order to lighten the ship so that it would be driven closer to the shore. In the evening the rising tide lifted the ship shoreward until the movement of the bow was stopped by the anchor cable. The stern continued to move towards shore resulting in the bow appearing to turn seaward.

The ship was held in this position for several days during which people and supplies were rescued. On 28 March, high surf conditions caused by onshore winds snapped the anchor cable and the ship was turned broadside to the surf. During the next high tide the vessel's bow turned shoreward and it was thrown more than its own length nearer to the shore. The vessel remained in this position until it finally disintegrated almost two years after the shipwreck.

An anchor visible at low tide was blasted off the reef in 1905 but other artefacts were not discovered until 1965, when another anchor was removed. Since then many smaller items have been removed by local divers. Investigation of the site commenced in 1983.

Characteristics of Excavation.

Recording and excavation of the site was carried out in 1985 and 1987 by the ***Sirius*** Project (Fig.2). The aims of the expeditions were to locate, plot and excavate artefacts and to assess the extent of ***Sirius*** wreckage (Henderson, 1984., Henderson and Stanbury, 1985, 1987). The excavation emphasis was to remove loose exposed materials rather then to excavate by trenches. An unexpected amount of material was found under the surf zone in Site 1 (rectangular area in Fig 2), but site conditions resulted in the adoption of a point methodology. This located an area of artefacts to a surveyed point rather then giving the locations of individual artefacts.

Muckelroy included the characteristics of excavation as a scrambling factor in his model because research aims and accuracy of recording can profoundly affect interpretation. The techniques used on the ***Sirius*** site had obvious limitations for a spatial analysis as they gave the spatial distribution of points rather than artefacts. However, the nature of the site reduced the adverse affects of the methodology, as water action had resulted in a distribution of small artefacts that was extremely clustered. For this reason the distribution between artefact areas was found to be adequate for the major purposes of this study.

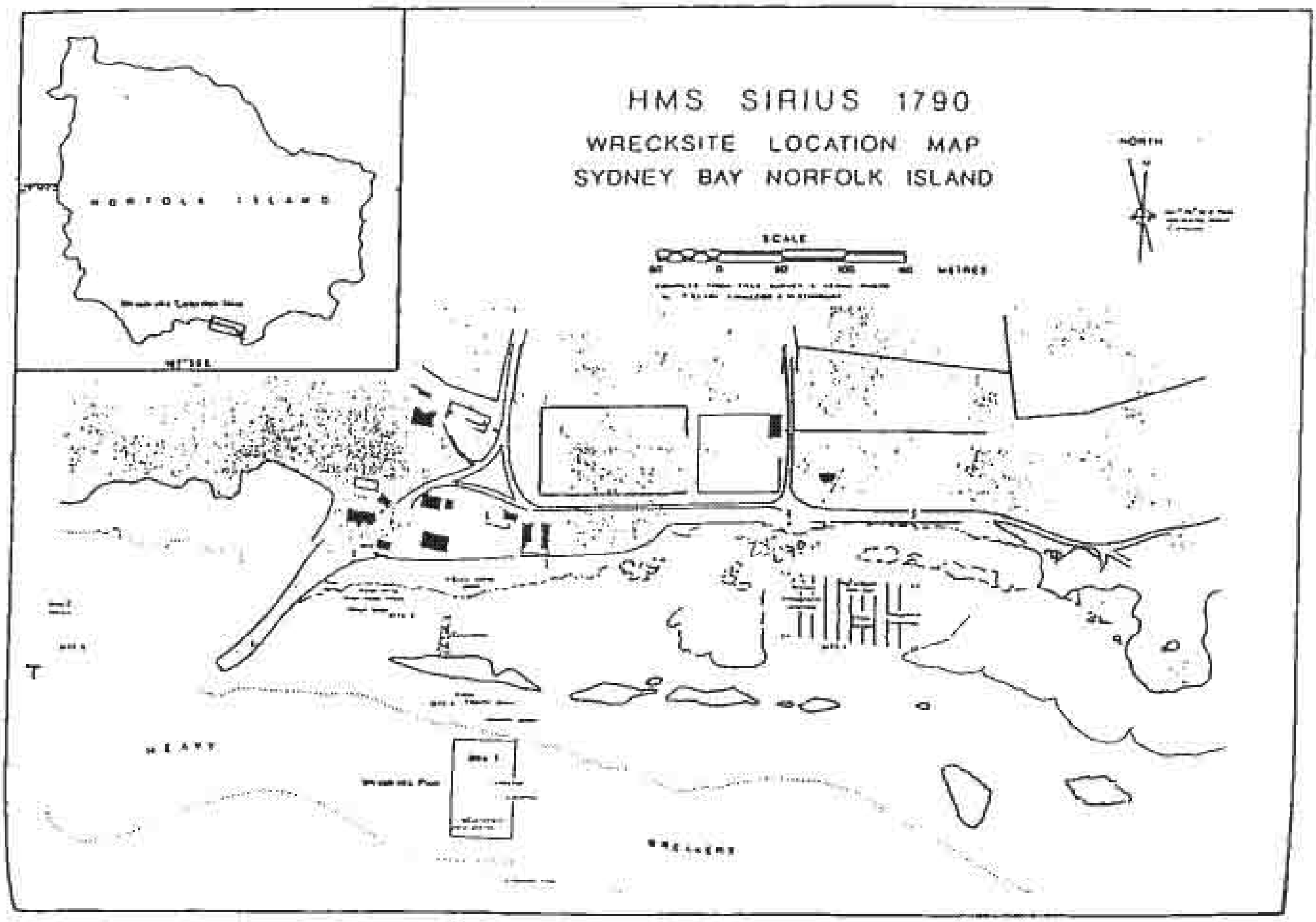


Figure 2 The wreck site of the *Sirius* (from Henderson and Stanbury, 1988).

Material Subsequently Deposited on the Site.

Later material deposited in Sydney Bay has been identified by archaeologists. This consists of most of the material from Sites 3,4 and 5. A ballast block in Site 4 is the only artefact from that site attributed to the ***Sirius*** shipwreck, and it is thought to be secondarily deposited. A spectacle plate and four copper bolts from Site 5 have been identified as ***Sirius*** material possibly belonging to the rudder.

Disintegration

Muckelroy saw disintegration as an extracting filter which loses information from the system. The question which follows naturally on from this view is, ' How much information has been lost?'

Understanding the processes of disintegration is vital to correct conservation treatment. Therefore most work in this area has been carried out by conservators. Pearson (1987) is an overview of this research which was then applied to the *Sirius* site.

The ***Sirius*** wreck site has warm water of average (35.77 ± 0.04%) salinity which is fully saturated with oxygen (MacLeod,1985). The site is in shallow water with a average depth of about 4 metres on the seaward side of Site 1, rising to about one metre near the ballast mound. Sites 1 and 2 are subject to extremely strong current forces as they are situated underneath a heavy surf zone. Sand-sized grains cannot settle in this area but are carried along by the water causing a sandblasting effect on artefacts. Outside the surf zone, seaward of the main site, and across Site 5 the presence of sediments is variable, currents across these areas being periodically strong enough to scour the sea bed.

In these site conditions, current research indicates that many artefacts may have been lost to the system through disintegration. The ***Sirius'*** cargo of provisions is likely to be archaeologically invisible within the main wreck site. However, casks may have floated away to a less severe area with sandy sediments to protect them. Very little timber from the ship would have survived unless part of the hull is buried under the ballast mound. Large iron artefacts would survive, protected by the massive concretions which form on corroding iron. These concretions would also incorporate and protect other nearby objects. Small metal objects of brass and iron have less chance of surviving but would survive if associated with the larger iron artefacts or a sheltered area. Many officers lost all or part of their personal effects as the salvaging method was to throw them overboard to float to shore. Metal fittings such as buttons, gun fittings, shot for guns and metal dishes fall into the small metal objects category mentioned above. However, organic material such as clothing is unlikely to have survived unless caught within a very protected situation. Glass and ceramic dishes are unlikely to survive intact within such a harsh environment but sherds may survive within gullies and in other protected situations.

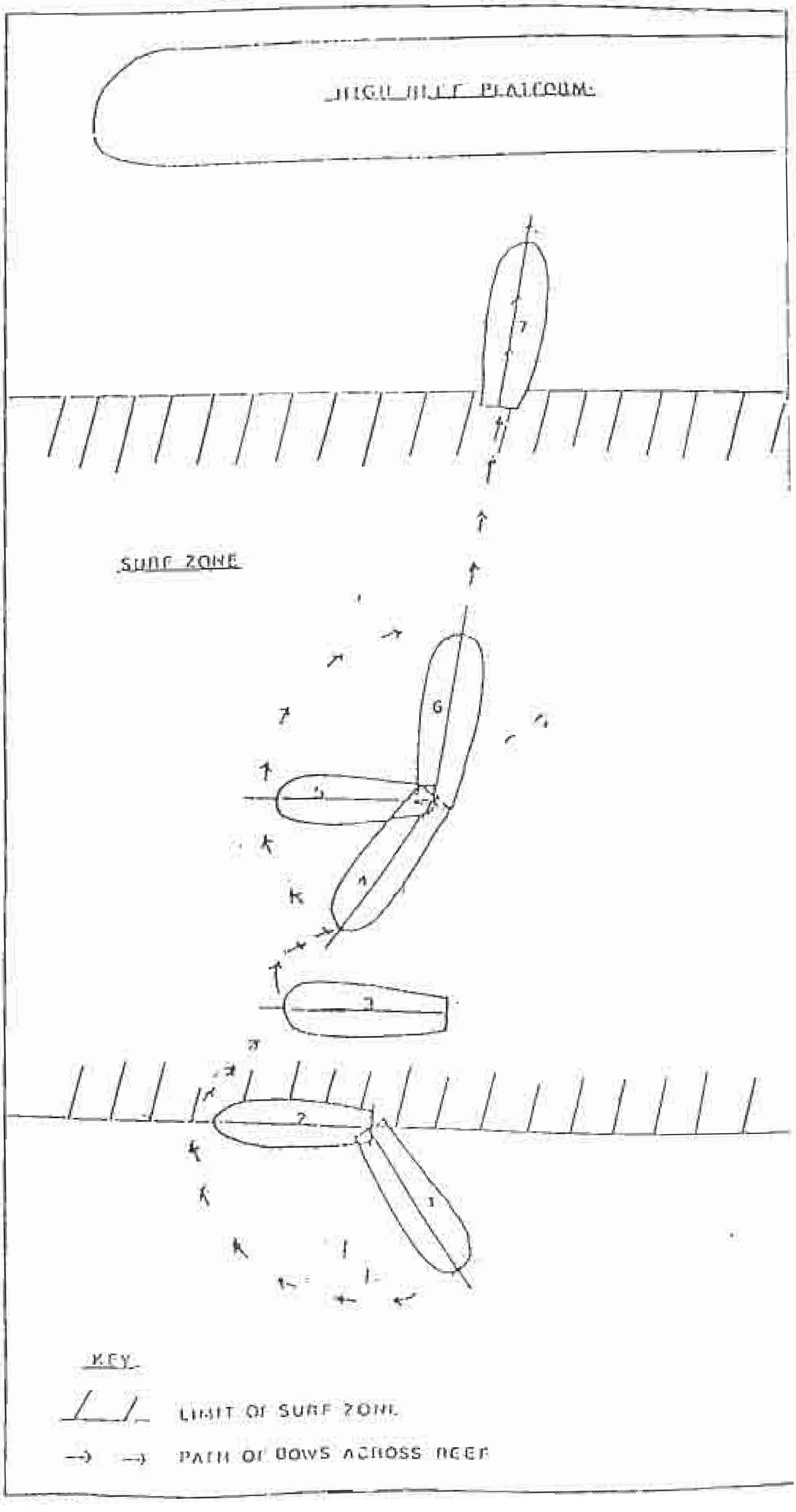
Examination of the effects of the site environment on artefact survival has shown that on this site only large iron objects were likely to be able to survive on the bare reef flats. The distribution of artefacts excavated from Site 1 (Artefact catalogue, Henderson & Stanbury, 1987) show this patterning with the majority of small objects being found within the gully system. This patterning is the product of site conditions and the excavation techniques rather then the process of wrecking as some small objects were found on the reef flats but were not excavated due to their badly eroded condition.

Study of the effects of the surrounding environment on the disintegration of artefacts can give archaeologists a better idea of the survival potential of various items, and their probable locations. Apart from helping to locate artefacts, knowledge of prevailing environmental conditions should help to highlight possible biases prevailing in the the archaeological record.

The question, 'How much information has been lost to the system?' may never be answered in quantitative terms. One reason for this is that in order to know what was lost, one needs to know how much there was in the first place. Incomplete or non-existent documentation result in this simply not being feasible for most vessels. In a systematic context, disintegration studies can be used to gain an idea of the survival potential of artefacts and to highlight possible biases within the archaeological record. They cannot be used to make any quantitative statements of loss.

Process of Wrecking.

FIGURE 3 Important Ship Positions.



It is important to establish where the ***Sirius*** hit the reef, and its subsequent movement, as the vessel moved some distance between its initial stranding position and its final resting position. To understand artefact patterning, the vessel's path over the reef must be recreated.

Historical eye witness accounts describe a series of movements which can be conveniently divided into seven major ship positions (Fig 3). However, the patterning of artefacts across the main site was difficult to explain by reference to the historical accounts alone. It was found that the effect of physical processes upon the process of wrecking had to be taken into account for any interpretation of the archaeological patterning to take place.

Several of the eye witness reports of the shipwreck are from naval men who included details of wind direction and strength, current direction and surf conditions in their accounts. These details were extracted from the diaries and tabulated into a form that would allow easy comparisons. This was then sent to the New South Wales Bureau of Meteorology. Mr J. James on behalf of the bureau identified that the most likely synoptic situation represented by the accounts was a deep low pressure system which had moved south/southeast past the island. The most likely origin of such a system was a tropical cyclone which had weakened as it moved south.

Such systems generate characteristic large wave trains which move outwards from the centre of the storm (Bureau of Meteorology,1983). Such a large swell reached the island on 19 March 1790, producing a strong swell-driven westerly current which completely counteracted the effects of the normal easterly flowing ebb tide. It was this strong westerly current coupled with the change to onshore winds which wrecked the ***Sirius***. Wind strength, which indicates the real onset of the storm, did not rise until the evening of the 19th, hours after the ***Sirius*** wrecked.

Having identified the type of storm which caused the shipwreck, this information can be used to model the conditions on that day. There are two main methods in current research for modelling water circulation systems; descriptive modelling and mathematical modelling. Mathematical modelling was beyond the scope of a honours thesis. However, the first step in creating a dynamic mathematical model is the production of a descriptive model against which to establish and test mathematical procedures. A good empirical descriptive model is capable of answering many questions which could be asked of a shipwreck, and was found capable of answering the overall needs of this research.

Having identified the conditions on the day of the shipwreck a descriptive model of the overall water circulation in Sydney Bay and a model of the circulation over the wreck site based on this information could be built. Eyewitness accounts, aerial photograph interpretation, reconstruction of wave refraction patterns and previous research on such systems was used in this reconstruction. Field measurements of current force and direction over the site were not available for use.

The reef in Sydney Bay is a shallow water fringing reef. Marsh et al. (1981) studied a similar system and found its main features were 11 currents moving shoreward over the surf zone, a longshore current on the shoreward side of the lagoon, and a rip system moving water back out to sea. Sydney Bay has two topographically fixed major rip systems and two minor ones. Because the rips are held in place by reef features, which comparison between modern and 1790 maps showed had not altered position, the placing of the rips on the day of the shipwreck was known. Bradley's 1790 map recording depths in the bay also showed that the major bathymetric features of the bay, which control wave refraction, were also much the same as present. This allowed the wave refraction patterns resulting from the wind directions recorded in the historical accounts to be recreated. Figure 4 is a recreation of the overall water circulation pattern in the bay at the time of the shipwreck. The rectangle indicates the position of the main wreck site (Site 1).

Across the wreck site this gross overall picture is modified by specific site topography. Figure 5 shows the approach of wave crests being modified by the spur and groove topography of the site and the resulting wave driven current directions. Underneath this wave driven shoreward movement is a pattern of oscillating currents which follow the line of wave movement. Return (rip) flow is strongest within the groove structure, which forms a north/south valley across the site. It is particularly strong within the gully system as is shown by debris within the gullies being concentrated at their seaward ends.

This interpretation of the current system and the spatial patterning of heavy metal objects on the site was used to recreate the path of the ship across the reef. Heavy metal objects were used, as these are presumed to be least affected by current forces. There has been no research in maritime archaeology to test the validity of such an assumption, and the use of a descriptive model precluded me from making such a test. However, the patterning of objects over the site gave reason to think the assumption was not too unreasonable. All artefacts found sitting on the reef flats were heavy metal objects, while smaller items were either caught in the gullies or found being swept backwards and forwards by the oscillating currents.

Figure 3 illustrates the sequence of movement described by historical accounts, along with the objects which were lost from the ship at various points. Figure 6 shows the spatial arrangement of heavy artefacts across the site. The anchor ring in grid square 9E (which marks the position of a anchor raised in 1973), the anchor and carronade position at Area 0 (marked with an X) and the anchor at Area 9 were used to locate the first four ship positions on the reef. The anchor ring is between the main stranding site and the five fathom line, which is the expected position of the Small Bower anchor. This establishes that the bow of the ship passed close to this position as the vessel moved backwards towards the reef. The carronade was carried overboard when the masts were cut down. The masts fell to the starboard, so the carronade must mark the starboard line of the hull in position 2. The anchor in Area 9 marks the extent of archaeologically proven eastward movement across the site. The archaeological site is not normal to the shore, thus any ship movement shoreward was in a northeast direction across the site. The position of the anchor in relation to the other material would indicate that it is associated with position 4. It is unlikely that position 4 is further to the east, as a minor return flow system operates to the east of the site. A vessel with most of its length affected by this return flow would be pushed out to sea, but this is not the situation described in the six eyewitness accounts.

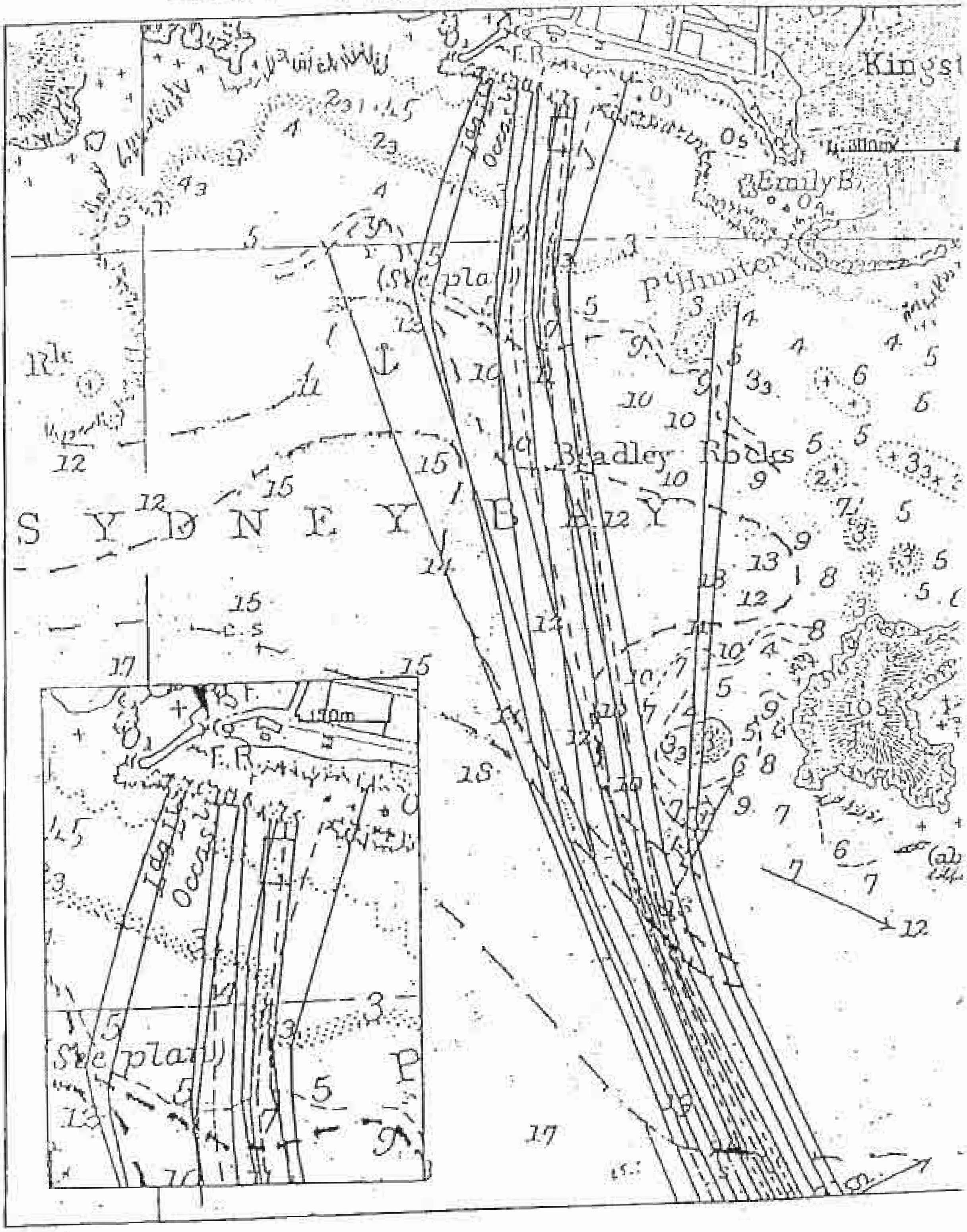
The three anchors and the carronade have a limited number of possible positions on board the vessel, but these could produce different interpretations of the ship position on the reef. Historical accounts agree that the vessel was checked in its shoreward movement between position 3 and 4, and that the ship was held in position 4 by the effect of the anchor cable. This can be used to determine between different interpretations, as it follows that the distance between the Small Bower anchor in grid square 9E and the bows in position 4 must be greater than the distance between this anchor and the bows at position 2 for any given recreation. Only one of the possible recreations fulfils this criteria. Shipboard positions for the anchors and carronade in this recreation are; Small Bower anchor on the port bow, carronade from the starboard bow position, making the anchor associated with it the best bower anchor also from the starboard bow and the anchor at Area 9 a spare anchor carried on the port side of the vessel.

These ship positions, illustrated in Figure 7, are supported by the independently created model of site currents. Position 1 is closely aligned to the angle of wave approach, and the turning of the ship into position 2 follows the turning of the waves towards shore. Currents operating on the ship in position 2 would cause the vessel to stay broadside to the surf as it moved towards shore, until the checking of the bows by the anchor cable caused uneven movement. With the bows checked, the untethered stern would continue to move shoreward causing the apparent turn of the bows seaward into position 4.

The ***Sirius*** stayed in this position until 28 March 1790 when, under the strain caused by large swell conditions, the anchor cable parted. Historical accounts describe the ship turning its bow towards the shore, then leaping more then its own length closer to the shore. This movement would not take the vessel across the main artefact area which is to the northwest of Area 9. To cover all known artefact positions a change from northeast to northwest movement is needed. Most of the physical factors affecting the vessel during this second period of movement were the same as for the first period which produced northeast movement. However, one factor had changed significantly, and this was the weight of the vessel due to the salvaging of most of its contents. The change in the ship's weight would have made wind direction more effective as a moving force, producing a westerly movement during high tide periods when the ship was semi-floating.

The change in the response of the ship was noted in the historical accounts and attributed to the lightening of the vessel. Salvaging, in this case, has clearly affected the pattern laid down by the process of wrecking, by altering the ship's responses to site conditions. This is a possibility that Muckelroy has overlooked in his model, which clearly has salvage coming after the process of wrecking, with no feedback into this process.

FIGURE 4 7 Second Period Wave Refraction Diagram



KEY

fathom contour

wave orthogonal

FIGURE 5 WAVE DRIVEN CURRENT PATTERNS.

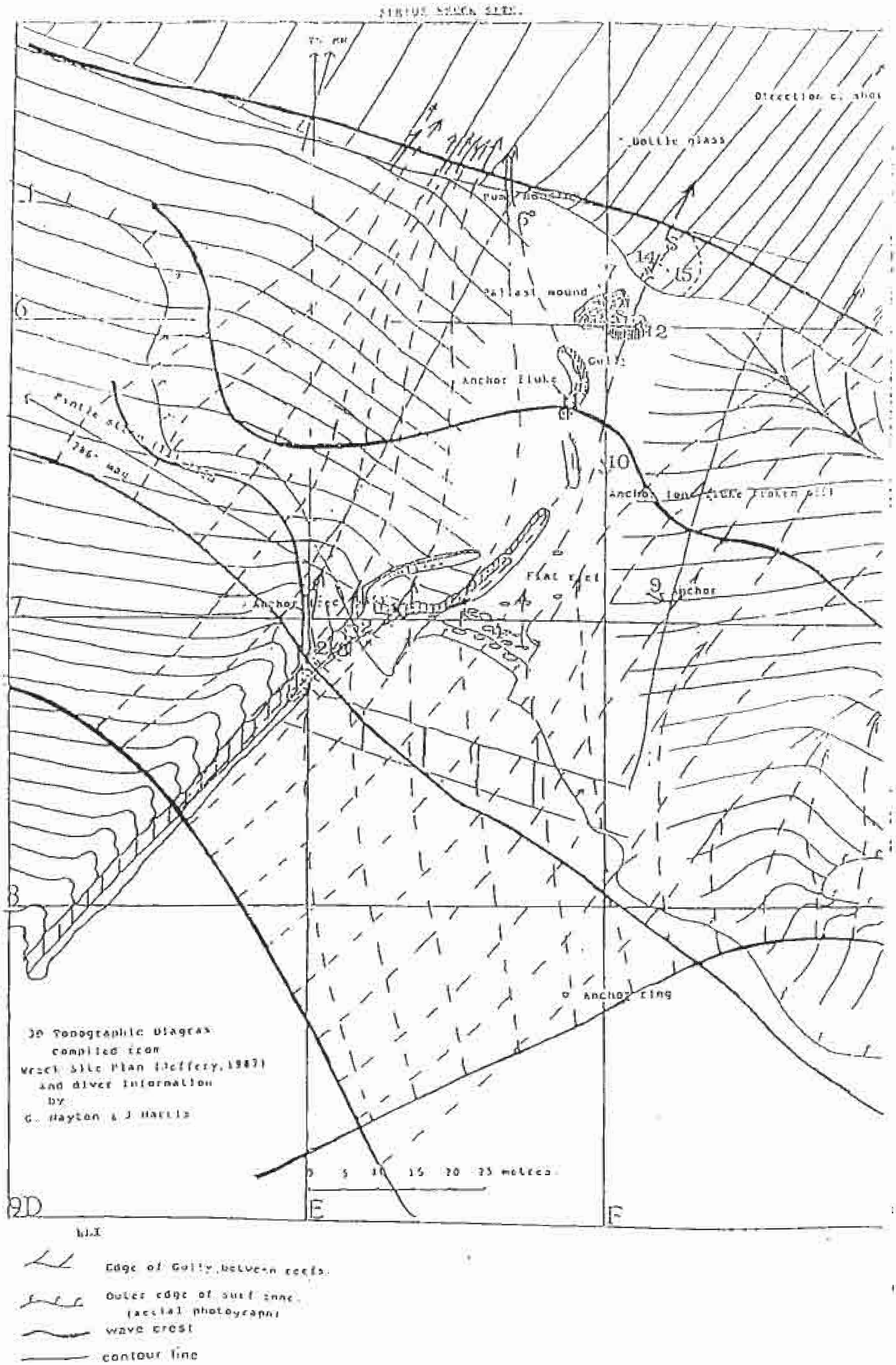
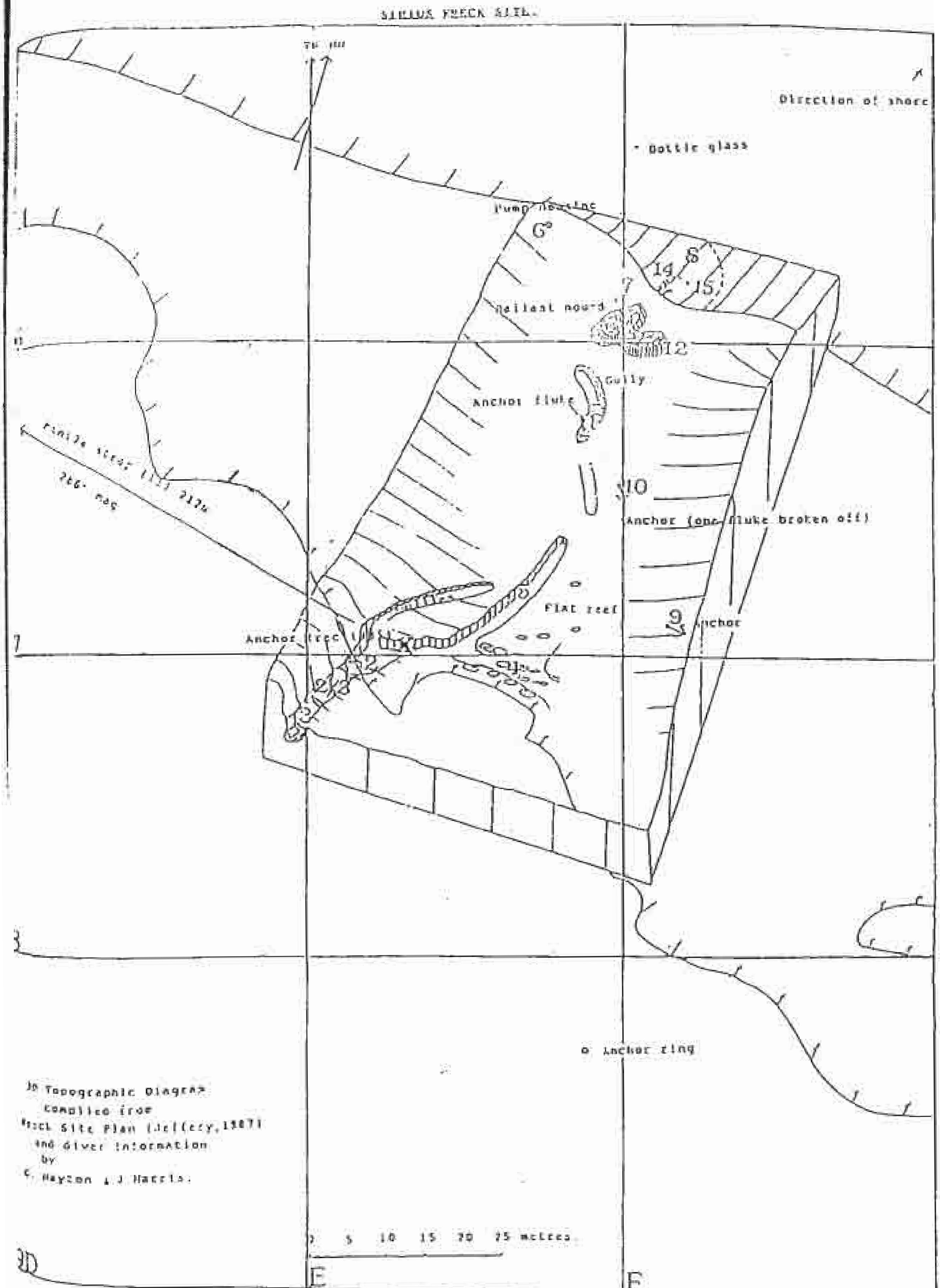


FIGURE 6 3 D Site Plan.



KEY

Edge of Gully between reefs

Outer edge of surf zone (aerial photograph)

The turning of the vessel described by historical accounts would have been produced by an unequal distribution of energy being delivered to the hull. This would have been caused by the spur and groove topography of the site leading to higher wave heights (therefore higher energy) within the groove across the middle of the site. As the ship's bow was pushed westward across the groove, this higher energy caused the bows to turn by a series of lifting and dropping movements, until by low tide the vessel was again broadside to the surf. The description of the turning of the vessel and its leap to its final resting position suggests that this movement was violent. Wave refraction patterns suggest a concentration of wave energy along the western edge of the archaeological site, producing more violent energies here than over the rest of the site. The most likely interpretation of ship position from the modelled site conditions would be that a ship moving westwards across the site would turn gradually until the bow of the ship protruded into the zone of higher energy, which would then act to fling the bow of the vessel shoreward.

The position of the anchor (Area 10), anchor fluke (Area 1), pump housing (Area 6) and the ballast mound have been used to position this movement across the site. Eyewitnesses believed that the vessel lost ballast from the bows before or during this turning movement. The described method of movement by a series of repeated shocks would have caused damage to the hull, but only one ballast block has been located near this part of the site. This block is different from the other two raised from the site and is also different from Admiralty regulations. This raises doubts about this block's inclusion as part of the ***Sirius*** artefacts so it has not been taken into account in this reconstruction. However further research on the ballast blocks still on the site may confirm its status.

The anchor at Area 10 is broken, and along with the anchor fluke at Area 1 is likely to have been carried as ballast. Carrying broken anchors as ballast was common naval practice and the position of these artefacts helps to locate the path of the turning vessel.

The piece of pump housing is from the pump well located in the centre of the ship. At 38 kg this is the smallest of the individual large metal artefacts used to position the ship, and as such, the most susceptable to seabed movement. Its position in relation to the other artefacts and current patterning across the site suggest that it has in fact moved.

Currents do not flow between Area 6 and the ballast mound therefore position 5 cannot be related to the ballast mound as this would not explain the position of the pump housing. Also position 5 cannot be related to area 6 as a ship with its midship section across Area 6 would be pushed into the gully between the reefs rather than to the ballast mound area. However, the currents across the middle of the ship position chosen as position 5 in Figure 6, would result in movement towards Area 6.

For this reason my model has the ballast mound marking position 6, rather than 5. The other alternative is position 7. It is possible that the ballast mound marks the final resting position of the ship (position 7), but this does not agree with historical accounts that state that the ship lay outside the reach of most surf, within easy wading distance of the high reef platform, and a ship's length away from where it turned. The ballast mound is within the surf zone, in a difficult area for wading due to breaking waves, and is much less than a ship's length away from the anchor marking position 4. In fact, it is only just a ship's length away from the initial stranding site. The historical accounts argue for position 7 to be within Site 2, (the gully between the reefs) which is inshore from the main area of breaking waves.

The loss of the principle high density material left on the ship in position 6 would cause a dramatic lightening of the vessel. This would change the ship's response to site conditions, making wind and waves much more effective moving forces. Such a change of response is documented by the historical accounts which at no other time during the shipwreck record a degree of movement that could be described as a large leap. Therefore, on the evidence available I have modelled the ballast mound as marking position 6, with position 7 within the gully between the reefs.

Salvage.

Muckelroy sees salvage as an extracting filter removing artefacts from the site. In his discussion (Muckelroy,1979:166) his assumption that salvage occurs after the process of wrecking is emphasized. This research has already invalidated this assumption. Another assumption is that salvage simply results in extraction of artefacts. This is true only for successful salvaging, unsuccessful salvaging can result in a scrambling of the pattern laid down by the process of wrecking.

This happened on the ***Sirius*** site, most noticeably in the category of artefacts relating to officer's possessions. Reconstruction of the floating pathways of items thrown overboard during both ebb and flood tide demonstrated the likelihood of contamination of Site 1 with goods lost during salvage. This means that the spatial distribution of officers' possessions cannot, on this site, be used to ask questions about the spatial patterning of such items on board the ship.

Reconstruction of the floating pathways of casks of provisions lost during salvage indicated an area where such material may be concentrated, in conditions more suitable for their survival. This area was the sandbank built by the head of the closest major rip current. Provisions were salvaged during the half tide period to allow use of a hawser and traveller set up between the ship and the high reef platform (which is dry at half tide). Casks lost out of the traveller during these conditions would have mainly entered the return flow system dominated by this rip current. Current force in the rip head is less then in the rip stream, causing the water to begin to drop its sand load, so casks may also have settled in this area. A search of any other area is extremely unlikely to find traces of the casks, as the evidence is slight and the area of the sea bed which may contain evidence is extensive.

A study of the salvage priorities evident in the historical accounts demonstrated that much of the archaeological record from the ***Sirius*** site is the result of these decisions. High priority items such as stores and spirts were taken out of the hold before it was substantially damaged, then transported to shore by boat, raft or hawser and traveller, resulting in a high degree of successful salvage. Stores were a lower priority and were left in the hold until the provisions had been salvaged, resulting in a greater degree of loss when the ship's hull became damaged. Personal possessions were high priority to their owners, but not high enough to take up space on the hawser and traveller while the provisions still had not been saved. The result was they were thrown overboard to float to shore, resulting in heavy losses. These differential losses add bias to the archaeological record of the site, which will need to be remembered when asking some types of questions of the site.

The *Sirius* site also allows the opportunity to look at the effects of modern sport divers on an archaeological site. A catalogue of items salvaged by sport divers was compiled by Myra Stanbury (Norfolk Island Catalogue, Henderson & Stanbury,1985). This catalogue shows strong patterning, with 30 of the 36 items listed as coming from the site being of bronze or copper, with a definite preference for identifiable objects. Of the four iron items, three are anchors or cannon with the fourth being a ballast block, no small iron objects were raised. These large objects were raised for the purposes of public display rather then as a personal collection item like the bronzes.

The patterned nature of this information loss will have to be taken into account by maritime archaeologists working on sites accessible to sport divers which they fear may have been subject to salvage.

Seabed Movement.

Muckelroy sees sea bed movement in terms of sediment movement, but the ***Sirius*** site illustrates that another type of movement is possible; that of artefacts moving across a hard sea bed. This is a different type of movement to that of an artefact within sediments.

Nearly all smaller artefacts were found in gullies suggesting redeposition. Yet despite this, even items as small as sheathing nails showed strong patterning across the site indicating that the redeposition was from local areas. The patterning was revealed by mapping together groups of items that were related by function, such as various rudder fittings.

Only Areas 0,2,2/3 and 3 were completely excavated. This means that density trends between Areas 4 to 15 could not be established, but the volume of artefacts from this part of the site greatly exceeds that of the areas that had been totally excavated.

Rudder fittings - Most rudder fittings were salvaged by sport divers with little provenance information. Of materials recovered by archaeologists, the large gully system in the south-west area of the Site 1 contained only three lag bolts and two possible rudder fastenings. Without provenance for the rudder fittings salvaged by sports divers it is difficult to know if these items are as isolated as they appear. Area 1 contained two pintle/gudgeon braces, a pintle pin, ten nails, fifteen lag bolts and a forelock bolt. It suggests that at least a part of the rudder came into this area. Area 8 contained thirteen rudder nails and five lag bolts, which suggests the stern of the vessel may have moved across this area which would place the bulk of the ship within Site 2.

A pintle strap with a bolt was found in Area 11, 212 metres to the west of Site 1, and the spectacle plate was found by divers west of the pier. This patterning conforms to the expected pattern of drift of a heavy wooden object from the stranding site during the conditions present when the ***Sirius*** wrecked. The spectacle plate was situated above the fourth pintle, suggesting that most of the rudder was detached from the ship. Two pins, one pintle, four gudgeon straps and one gudgeon, were recovered from the southern part of Site 1 by sports divers, which suggests considerable damage to the vessel and to the lower half of the rudder.

Hull fittings- The catalogued hull fittings are almost all small items; no large iron timber bolts have been recovered. These small artefacts show strong patterning, which suggests the relative extent of damage to the hull as it moved across the reef. Items such as keel staples, copper sheathing fragments and sheathing nails within Areas 2, 2/3 and 3 suggest only superficial damage, although the presence of 18 planking nails indicate at least some damage to the hull underneath the copper sheathing. Area 4, at the extreme eastern end of the southwest gully system, contains similar artefacts but shows an increase in the number of sheathing nails suggesting more extensive damage to the sheathing.

The sheer number of planking and sheathing nails in Areas 1 and 8 might be seen as indicating much more extensive damage to the copper sheathing, while the presence of keel bolts and keel staples indicate damage to the actual hull. This picture supports the modelling of ship positions 4 to 6 across this area, as historical accounts report that during this time the keel was forced up into the hull, and the orlop deck collapsed.

Armament- There was a tendency for armament to be found in heaps, suggesting deposition from shot lockers. There are several types of shot on the site; case, cannister, grape and round shot comprising the ship's armament, and musket balls, lead shot and cartridges comprising small arms. The bulk of each type of shot was found in different areas. There were also spatial differences between distributions of different sizes of the same type of shot. The distribution of 13 mm lead shot and 18 mm lead shot was extremely clustered and concentrated in Area 8. The model of ship positions suggests this clustering was the result of storage in the filling room or magazine area of the vessel.

Stores- Items of stores are associated with Areas 1 and 8. Convict nails in Area 8 are also extremely clustered and appear to be the contents of a barrel. Their proximity to the lead shot and musket balls suggest storage within the forehold close to the magazine, or in the carpenter's stores located on the orlop deck above the magazine.

Conclusions.

A model of the process of wrecking was generated which integrated historical data and site formation processes to explain the pattern of artefacts recovered from the sea bed. The model documents ship movement and damage across the site, and mechanisms were found which explain the recorded ship movement. While based on the distribution of heavy artefacts, the archaeology of the small artefacts reinforces the model and agrees with historical documentation of damage to the ship.

This model was, of necessity, built up from a distance, both spatially and temporally. Field measurements of current force and direction during ebb and flood tides across Site 1 are needed to verify the current patterns on which the model is based.

Further excavation of the ***Sirius*** site took place in October 1988. Part of the expedition's aims was to record site information that may be used to test this model. This information has not yet been analysed so cannot at this moment be used to confirm or modify this model.

In relating this research to Muckelroy's concept, the building up of a model of the ***Sirius*** shipwreck has shown that the factors included in his flow diagram could be usefully assessed and applied to the ***Sirius*** wreck site. However, modifications of the original flow diagram were proposed, and the importance of the physical site formation processes emphasized.

Two major modifications were proposed (Figure.8); a feedback loop from **Salvage** to the **Process of Wrecking**, and the removal of the category of **Sea Bed Movement**, replacing it with the category **Total Artifact Movement**. This category was subdivided into two sections called **Artifact Movement Within Sediments** and **Artifact Movement Over Sea Bed**.

FIGURE 7 MODEL OF THE SIRIUS SHIPWRECK.

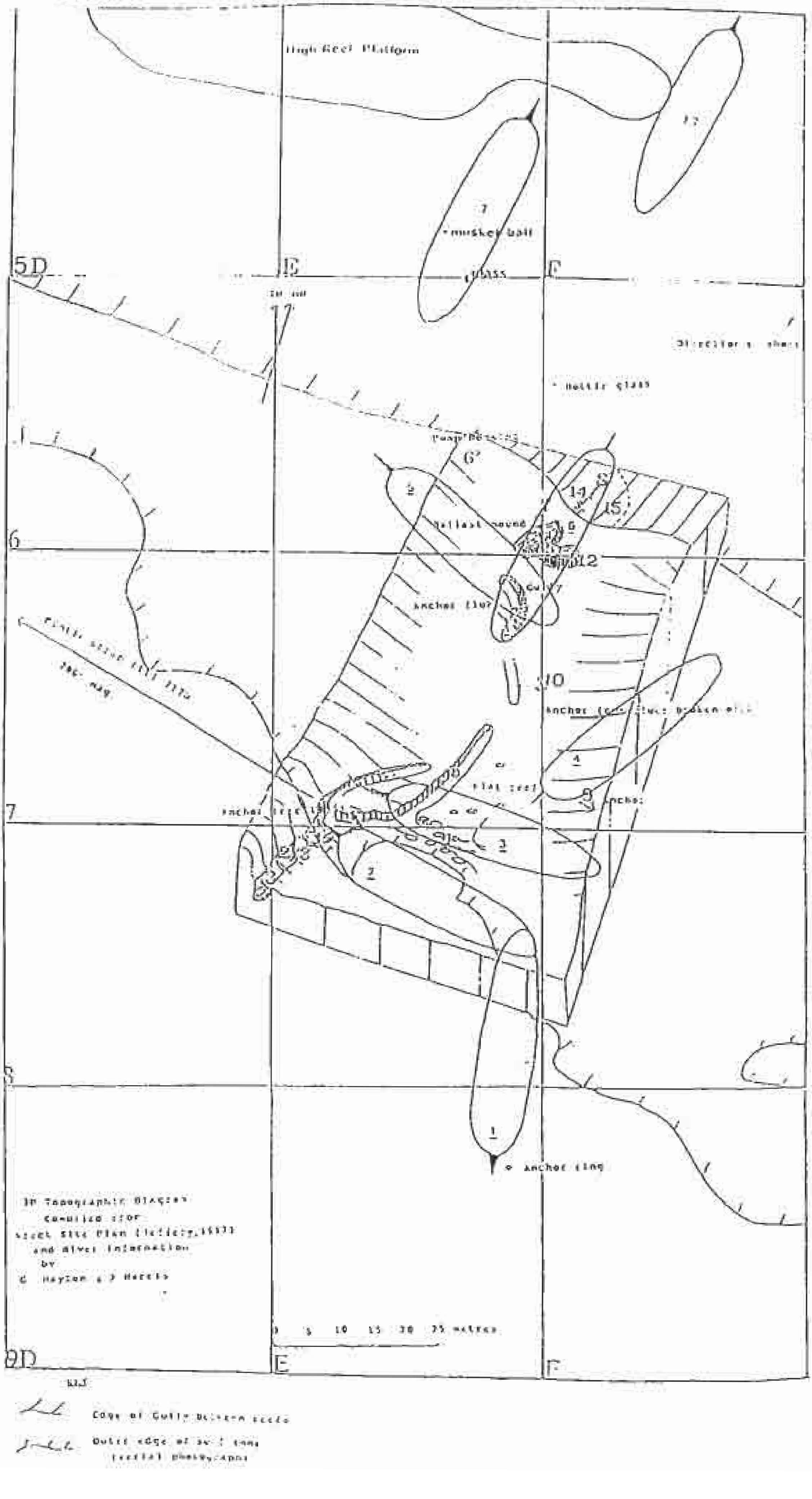
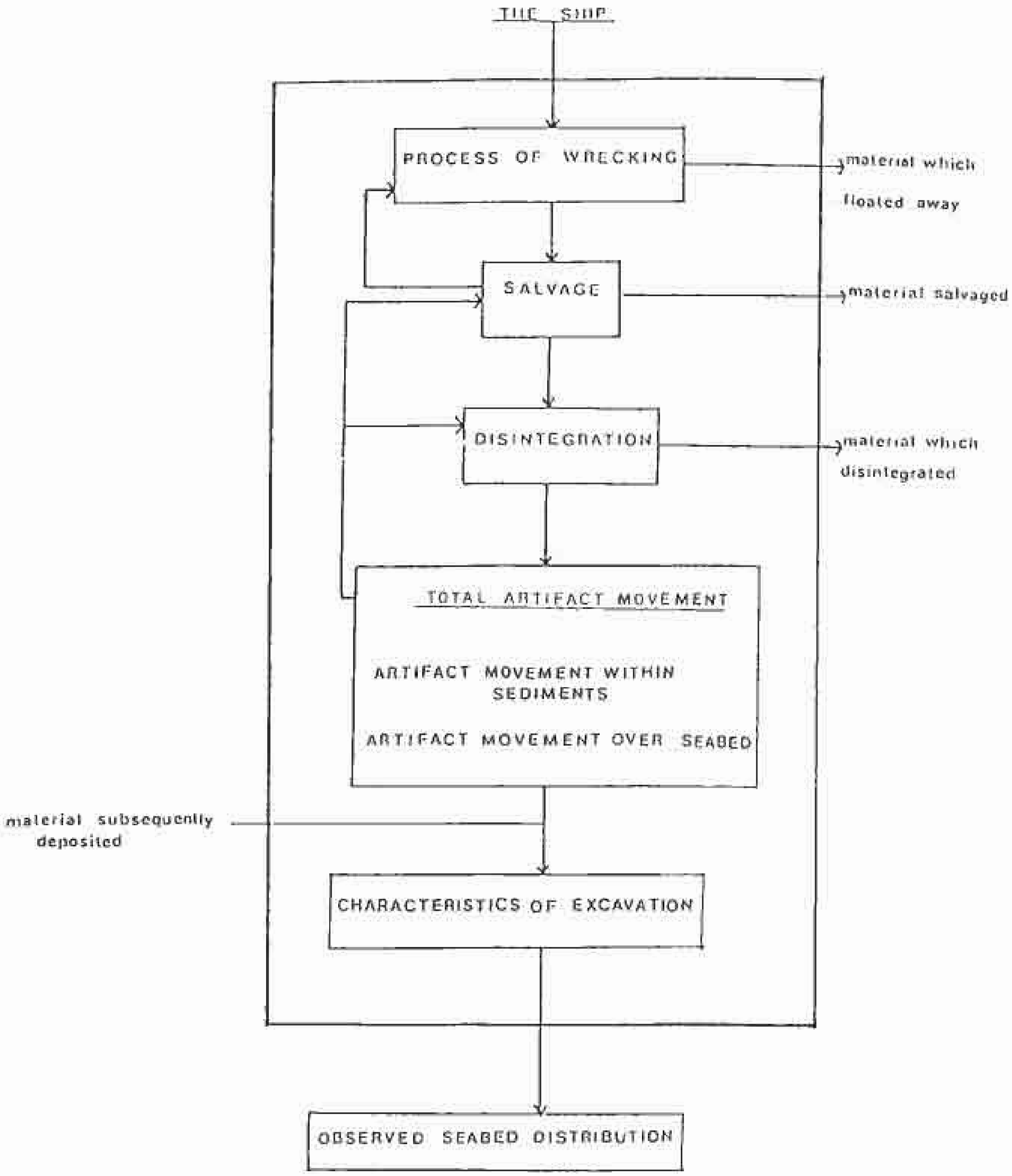


FIGURE 8 MODIFIED FLOW DIAGRAM OF A SHIPWRECK.



This systematic concept of a shipwreck proved to be an extremely powerful tool for use on a shipwreck with no coherent ship remains. It allowed all factors which had affected the patterns displayed in the archaeological record to be analysed. Using this concept should allow more valid interpretations of the distribution of artefacts across a site, the processes of the shipwreck, and the original spatial relationships of artefacts within the intact ship.

NORFOLK ISLAND GOVERNMENT PROJECT

1988 EXPEDITION REPORT ON THE WRECK OF HMS *SIRIUS* (1790).

Compiled by Graeme Henderson, with
contributions by Ian MacLeod
George Cresswell
Bill Jeffery
Gaye Nayton
Isabel McBryde
Alan Watchman
Geoff Kimpton
Tom van Leeuwen

DISCUSSION

The 1988 Expedition

Design 1

The fieldwork was designed to test several hypotheses:

Hypothesis 1A: **The *Sirius'* ballast was secured (that is, chained together as a matrix) over part of the ship's bottom.**

This was tested positively by close examination of the raised ballast pigs during and after deconcretion. Parts of chain links have survived in the securing holes drilled obliquely through each end of each pig. However it is not known whether all the pigs had chains. Nor is it known how long the chain links retained their strength while corroding on the seabed.

Hypothesis 1B: **The matrix was partially maintained during and after the process of destruction of the *Sirius'* upper works.**

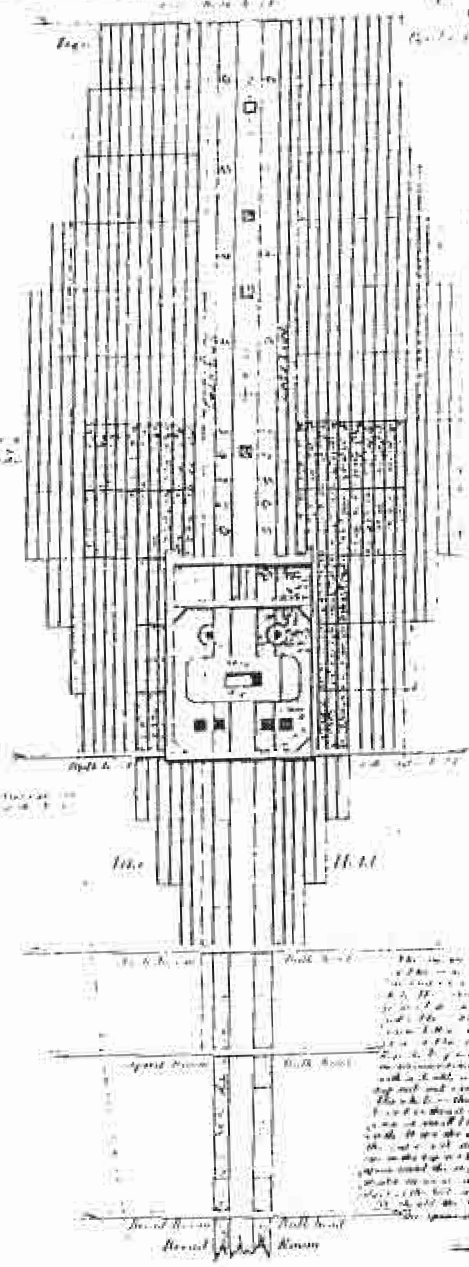
This was tested by physical observation of the pigs on the seabed. Nearly all of the ballast on the site consists of what was termed 'large ballast', being 3' by 6" by 5" and weighing 7 pieces to the ton, or 334 pounds (152 kilogrammes). The 1786 fitting out records indicate that the ***Sirius*** carried $28^{1/2}$ tons of iron ballast (191 pigs if entirely composed of large ballast), while the 1787 fitting out records indicate that an extra 140 pigs were added, making a total of 331 if all pigs were large ballast. During the 1988 expedition 210 pigs were counted. Where are the remaining 121 pigs? Some are undoubtedly obscured under the ballast mound and on other parts of the site. One had found its way inside the lagoon and was raised during the 1985 ***Sirius*** expedition. Heavy seas soon after the wreck could easily have pushed any unsecured pigs inshore; a concrete plinth placed in deeper water on the site during the 1988 expedition moved a considerable distance across the bottom during several days of heavy weather. The pigs would have been of interest to the salvors because they could easily be put back into use as ballast. Given that the guns were salvaged, the iron pigs at the shoreward end of the site would not have presented great difficulty to the salvors. Two pigs have been located on the Island; one in a shed, being used as an anvil and the other in a private museum. Two of the anchors located on the site are badly broken and were probably part of the ship's iron ballast. Assuming weights of 10 and 6 hundredweight these could account for another 6 pigs. Taking these factors into account it is clear that at least two thirds of the ship's iron ballast remains on the site.

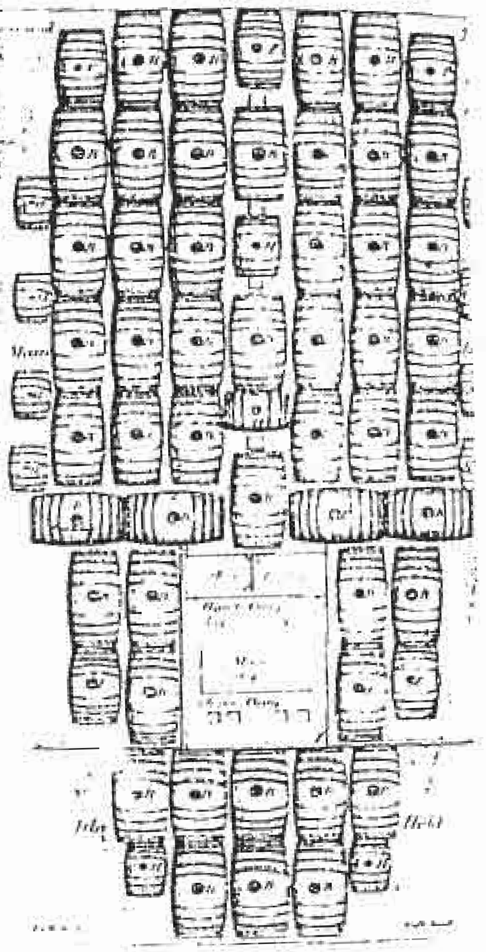
Two major groupings of ballast pigs were plotted on the seabed during 1988. The seaward grouping (including the two broken anchors) is seen as representing the ballast which dropped through the ***Sirius'*** bottom when the wreck moved shoreward on 28 March 1790. The ship's head, which had been facing seaward, swung around past the stern, to face the shore. The implication is that the dropped ballast came from the forward part of the ship, and that the consequent lightening of the forward section enabled the head to be swung round. The inshore ballast thus may represent that which had been placed midships and aft in the ship. The existence of a distinct inshore mound appears to indicate the position to which the ship moved on 28 March 1790.

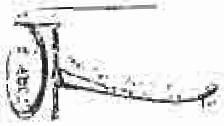
Hypothesis 1C: **The matrix was sufficient to allow preservation of elements of the ship's bottom.**

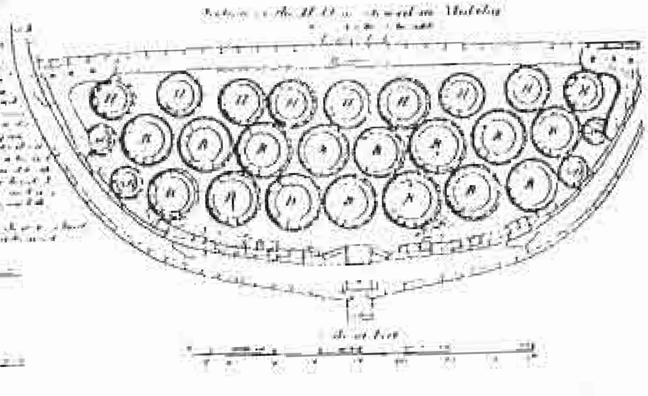
This was partially tested by surveying the ballast mound to establish orientation. It was also intended to excavate a transect through a dense area of ballast pigs to reveal any surviving timber structural elements. This has not yet been done because time ran out during the 1988 field season. A small transect was cut across the shoreward face of the mound. No underlying elements were found there, with the exception of several fragments of sheathing copper. This may indicate that some of the ballast pigs rolled shoreward, past the forward extremity of the ship, after the final break-up of the hull in 1792.

PRACTICE of STOWING a SHIP'S BALLAST

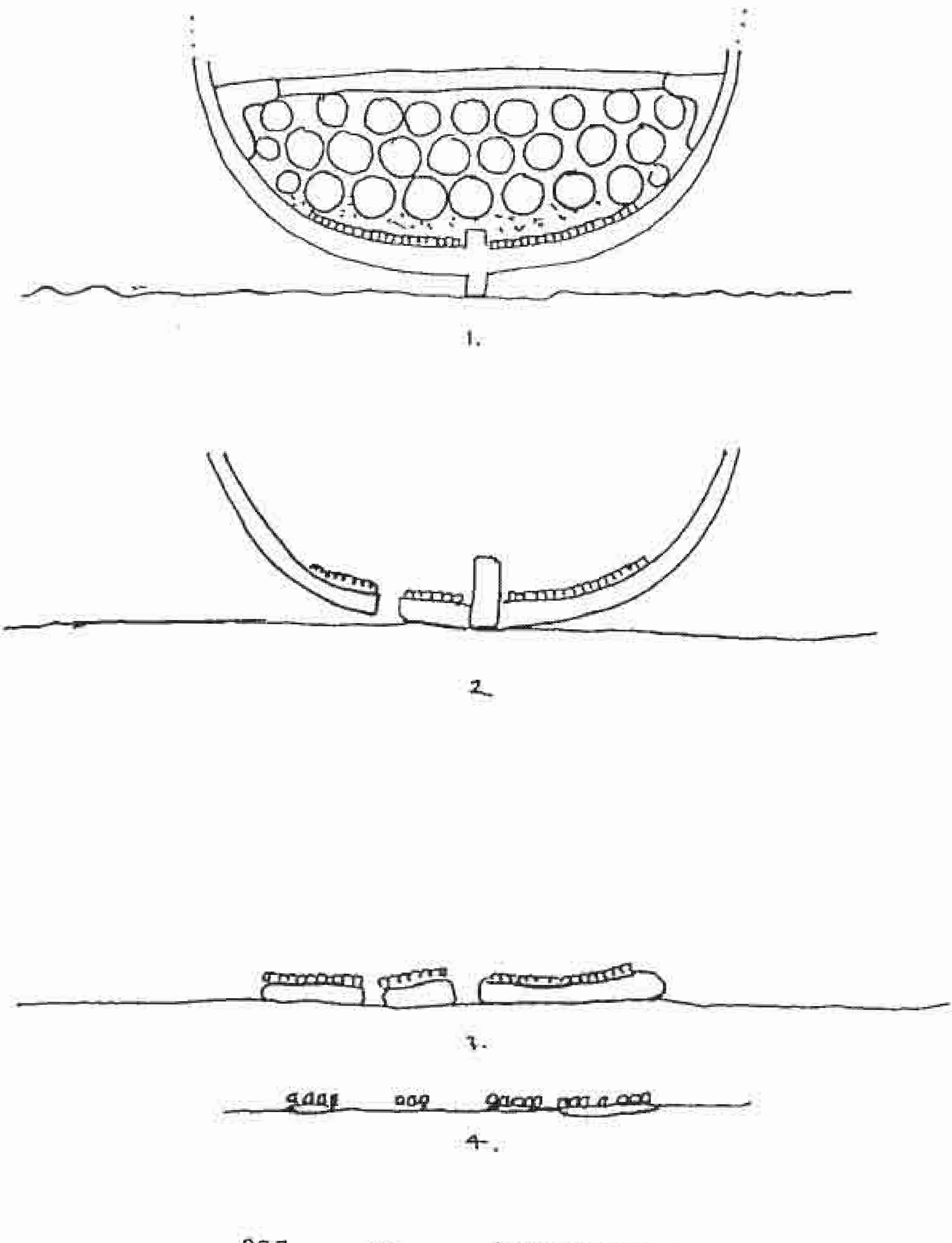








Victualling Measures



Suggested disintegration process.

Hypothesis 1D: **Examination of elements of the surviving ship's bottom will provide data relating to the nature of the construction and maintenance of the *Sirius'* hull, indicating a well constructed and reasonably maintained ship.**
This could not be tested because the transect through a dense ballast area was not cut.

Hypothesis 1E: **Examination of other fittings from the wreck will also provide data indicating the vessel's condition to have been reasonable.**
Progress was made in testing some fittings.

A) Anchors.
Five anchors are known to have been left on the site after the salvage efforts of the 1790s were completed. The seaward anchor, which contemporary sources indicate was the small bower thrown overboard before the ***Sirius*** struck, was raised by local skindivers in 1973 and is now in the ***Sirius*** Museum at Kingston on Norfolk Island. Its position on the site is indicated by the ring, still concreted to the seabed. The small bower is 15' 1" long, indicating, according to Steel's 1809 tables, a 34 hundredweight anchor. The best bower, located on the bows t the ready on naval vessels, would have been the next anchor dropped. It was raised by the ***Sirius*** Expedition in 1985, and is now in Sydney, on loan from the Norfolk Island Government to the Australian National Maritime Museum. The best bower measures 14' 11" in length, indicating according to Steel's 1809 tables, a 33 hundredweight anchor. However, this piece is marked with what appear to be the letters '28', perhaps indicating a 28 cwt (1422 kg) The anchor weighed approximately 1400 kg when weighed during treatment. A little inshore from the original site of the best bower is a fluke, concreted to the seabed and marking the position from where the sheet anchor, now at Macquarie Place, Sydney, was raised in 1905. The sheet anchor measures 15' 1" in length, indicating a 34 hundredweight anchor.

Two other anchors lie further inshore. The outer anchor is the larger. Both palms are missing, together with the extremity of the shank beyond the notch for the stock. The remaining shank length of this anchor is 3.35 metres (10.99 feet), indicating a 12 hundredweight anchor. The inner anchor has one palm missing, and the other is badly damaged. This anchor measures 2.88 metres (9.45 feet), indicating an 8 hundredweight anchor.

Steel (1780) and his contemporaries state that in the navy, best and small bower, and sheet anchor, do not vary in form or weight from each other, but that stream and kedge anchors are considerably smaller. Steel's (1809) 1809 Establishment of anchors for 20 gun and 24 gun ships and a 481 ton sloop is as follows:

20 guns	bowers	4 each	25 cwt	total 100 cwt
	stream	1	7 1/2	
	kedge	1	3 1/2	
24 guns	bowers	4 each	29 1/2 cwt	total 113 cwt
	stream	1	7 1/2	
	kedge	1	3 1/2	
481 ton sloop	bowers	3 each	25 cwt	total 75 cwt
	stream	1	7 1/2	
	kedge	1	3 1/2	

If the broken anchors represent the ***Sirius'*** stream and kedge, and if no anchors were taken from the site during the 1790s salvage, then its mooring equipment could be tabulated as follows:

Sirius 20 guns	bowers	3	33, 28 and 34 cwt	total 95 cwt
	stream	1	12 cwt	
	kedge	1	8 cwt	

However it is unlikely that this represents the ***Sirius'*** suite of anchors. The sizes of the two bowers and the sheet are almost as we would expect, given that Phillip had his bowers and spare replaced with several larger anchors at the commencement of the First Fleet voyage. The 'kedge' on the other hand seems far too heavy for a vessel of the ***Sirius'*** size.

A more likely scenario is that the two smaller (and badly broken) anchors were being carried as ballast. This raises the question of whether the ***Sirius*** had an adequate suite of anchors. Early nineteenth century sources invariably stipulate a requirement for four 'major' anchors on a vessel of the ***Sirius's*** size, whereas, as late as 1769, Falconer claimed that 'every ship has, or ought to have, three principal anchors'.

The Journals do not refer to any anchor losses by the ***Sirius*** after leaving England, so the likely explanation is that several anchors - a third bower, a stream and a kedge, were salvaged from the wreck in 1790.

The principal anchors demonstrably in use at the time of the wreck were clearly in good order and more than adequate in size.

B) Cannon.

Historical sources indicate that all but two of the guns were raised during the 1790s. The whereabouts of two of these guns (18-pounder carronades on Norfolk Island and on the wreck site) is definitely known, while a third (a 6-pounder located in Sydney) has been tentatively identified but not examined in detail by *Sirius* Project members.

Of the two 18-pounders, one remains on the wreck site, heavily encrusted, and its condition, although apparently sound, cannot yet be determined. The other, raised in 1985 by the ***Sirius*** Expedition, is still undergoing preservation treatment on Norfolk Island. This piece shows evidence of extensive superficial chipping having occurred prior to or during the wrecking of the ***Sirius***. The chipping seemed initially to be a possible indication of a poorly maintained gun, but preliminary research by Dr Ian MacLeod on the high sulphur content of the gun metal suggests that this may be the reason for the chipping, and if so, it may be an indication of the times rather than an indication of neglect of the item on board.

Other than this piece there seems to be nothing in the historical record to suggest an inadequate suite of guns. The carronades could not have been very old; the first use of a carronade being in 1779 (Lavery, 1987: 105).

C) Pump.

A bronze pump tube was raised from the site in 1985. Naval ships of the period generally carried both chain pumps and wooden barrelled common hand pumps. No obvious elements of either of these have been seen on the site, but that does not indicate that they were not present on the ship.

Several forms of hand pump might have been present on the ***Sirius***. By an order of 1743, hand pumps were to have 1/4 inch thick brass chambers fitted to them, being 22 inches long, with a 5 inch bore and weighing about 30 pounds (Lavery, 1987). The lower inside edge of the chamber was chamfered to prevent the 'box' or cylinder from catching.

Falconer (1815) refers to another hand pump, recently invented by a Captain George Truscott of the Royal Navy, for use in ships of war. Called the patent pump, it was composed of a metal barrel, nearly three feet long, with two boxes and two bolts, upon which the spear was secured, and it was worked by two iron handles directly opposite each other. These pumps were usually placed near the fore hatchway, on the orlop deck. They were fitted with two lead pipes: the lower with branches leading into the holds and extending via leather pieces into the bung hole of casks. The pumps drew water from the barrels and conveyed it to an iron tank on the main deck and then into boilers for cooking provisions. Falconer noted that this sort of pump had already been supplied to many naval vessels.

The fitting found on the ***Sirius*** more likely fits the former pump. Similar bronze barrels have been found on the wrecks of the ***Pandora*** (1791) and the ***Rapid*** (1811).

D) Iron Knee.

An iron knee was observed on the ***Sirius*** site during the metal detector survey of 1988. The 'L' shaped piece has arms some 30 cm and 75 cm in length. It is possible that the iron knee derives not from the *Sirius* but from the *Renaki* , a large iron-kneed sailing vessel wrecked some 200 metres towards the pier during the 1940s. Without close analysis of the item in a laboratory it is not possible to be sure that it comes from the *Sirius* , but it is worthwhile assuming, for the moment, that it does come from *Sirius*. Although most ships of the late eighteenth century were still equipped with wooden knees, iron knees were not uncommon. Some of the knees of the *Invincible* (a British warship of the 1740s) for example were of iron (Lavery, 1988: 81). There was lingering suspicion of the qualities of iron knees by many naval architects as Steel indicated in 1805:

> In those parts of a ship afore and abaft, when wood knees cannot be procured of kindly growth (for upon that depends the strength) knees of iron are generally placed. These, although they are now much used, particularly in merchant ships, cannot be so fully depended upon as those of wood, because they cover less surface, are nowise flexible, nor can the bolts be driven so tightly in the iron as in the wood. If, therefore, the ship strains, they must inevitably work loose...

The historical records do not indicate whether the *Sirius* was built with iron or wooden knees, but it is clear that good ships were built of either.

The examination of the above fittings is not yet complete, but current indications are of a reasonably built and maintained ship.

Design 2

Applying Muckelroy's variables to the *Sirius* site we have:

1. Maximum offshore fetch: more than 750 kilometres.
2. Sea horizon from the site: 44°.
3. Percentage of hours during which there are winds of force 7 (28-33 knots) or more:
4. Maximum speed of tidal streams:
5. Minimum depth of site: approximately 1 metre.
6. Maximum depth of site: approximately 2metres.
7. Depth of principal deposit: aproximately 1 metre.
8. Average slope of the seabed: 1 in 140
9. Underwater topography: less than 10%
10. Nature of the coarsest material: boulders
11. Nature of the finest material: sand

According to these environmental attributes the *Sirius* site would fit somewhere between Muckelroy's Class 4 and Class 5. His Class 4 sites yield virtually no organic material, but do have a wide range of artefacts representing a broad cross section of the ship's contents. In some cases the seabed distributions are evidently of some archaeological significance, in reflecting the process of wrecking. Muckelroy's Class 5 sites are those which have really been smashed up by natural forces, and on which only heavy metal and stone objects survive, often in heavily abraded condition. The distributions of the material over the seabed are usually of limited significance.

Design 3

Data was collected with a view to assessing the rate of drift on the day the *Sirius* commenced offloading, but the likelihood of seasonal variation reduces the value of data obtained in October.

Nayton Model

a) Regarding the final resting position of the *Sirius*, the data collected during the 1988 fieldwork appears to be at odds with the conclusions drawn by Nayton. Nayton places the vessel in a channel leading into the inshore lagoon, or in a depression just outside the lagoon. However the 1988 fieldwork showed the major grouping of ballast pigs to be some distance seaward of these positions, and it is argued that the ballast mound represents the final position. If a transect cut through the centre of the mound reveals hull structure it will resolve the issue.

b) Metal detector surveys were conducted through the depression just outside the lagoon, where some ballast pigs were revealed, but little else. A metal detector and visual survey conducted from that depression seaward along the east and west sides of the ballast concentrations revealed nothing on the east side, but several items on the west side, including an iron knee, a loose anchor ring, and an anchor fluke. The anchor fluke, cemented heavily to the seabed, would not have moved since the wreck, but the anchor ring appears likely to have been driven shorewards by the currents since an anchor was raised in 1905, while the iron knee may well have been driven seawards at the time of the wreck.

CONCLUSIONS

Although the ***Sirius*** Project is not yet complete, almost all of its original aims have now been achieved. The site has been declared and thus given the full protection of the Commonwealth Government's *Historic Shipwrecks Act, 1976.* Divers are free to swim on the ***Sirius*** wreck, but cannot legally remove material without a permit from the Department of the Arts, Sport, the Environment, Tourism and Territories. The site has been surveyed and described. Exposed and loose material has been removed from the site by maritime archaeologists, and recorded and analysed. The objects raised have been or are in the process of being conserved by Norfolk Islanders and scientists from the Western Australian Maritime Museum. The material is housed in the care of the Curator on Norfolk Island. The Norfolk Island Government has acted upon advice from the Museums Association of Australia and the Western Australian Maritime Museum on the longer term conservation, housing, and display of the collection. A building has been selected and plans are being put into effect. A museum devoted to material from the ***Sirius*** is scheduled to open in March 1990.

The communities of Norfolk Island and mainland Australia have been made more aware of the historical and archaeological significance of the ***Sirius'*** remains in the short term by means of public lectures and media releases. Some forty members of the press attended the press conference arranged in Sydney immediately after the 1987 expedition to the ***Sirius*** site was completed, and approximately half that number travelled to Norfolk Island during the 1988 ***Sirius*** Expedition, an indication of the strong public interest in the project. Longer term arrangements have included assistance in the production of a documentary film by Richard Swansborough, and technical progress reports, as well as a semi-popular book, which described the project's progress until just before the 1988 Expedition. The inclusion of ***Sirius*** Project material in two major national travelling exhibitions during 1988 - the Australian Bicentennial Exhibition and the *Shipwreck!* exhibition - also contributed to that community awareness. The Project has shown the old view of the ***Sirius*** - that of an East Indiaman burnt to the waterline, shabbily rebuilt and left to rot for some years before an inadequate refit and re-commissioning - to be no longer tenable. It is now clear that the vessel was built as a Baltic trader, and that it fits closely with the model of vessels used for scientific and exploration voyages in the Pacific. These conclusions support one element of Alan Frost's argument for a well considered and permanent approach by the British Government to the colonisation of Australia.

The ***Sirius*** Project, as first conceived, was scheduled for completion in 1987, and the Australian Bicentennial Authority's funding followed this schedule.

But several challenges remained. The historical and archaeological questions posed in 1987, after the principal archaeological deposit was found, invited further exploration; what was the ***Sirius'*** condition and suitability at the commencement of the First Fleet voyage, and what was involved in the process of transformation from warship to archaeological site? To pursue these questions the October 1988 expedition was conducted. Good progress was made in the generation of relevant data, but the time in the field proved not to be sufficient. Further archaeological and historical research is necessary for the resolution of the questions posed.

The 1988 fieldwork season provided the opportunity for the Norfolk Island Government to enhance the heritage potential of the ***Sirius*** site in several other ways. The Norfolk Island Government has custody of the ***Sirius*** collection under a Memorandum of Understanding with the Commonwealth Government. To best ensure that the material could be enjoyed by all Australians, a collection of artifacts, including the newly conserved sheet anchor was sent as a loan in October 1988 to Sydney, to be displayed in the Australian National Maritime Museum.

The ***Sirius*** Management Plan is another example of positive initiative being taken by the Norfolk Island Government to promote the heritage value of the ***Sirius*** site.

A brief expedition to the ***Sirius*** site is planned by the Norfolk Island Government for March 1990. The site condition will be monitored, and progress with the conservation of the collection reviewed. It is fitting that the Management Plan should be put into effect on the occasion of the 200th anniversary of the sinking.

RECOMMENDATIONS

A draft Management Plan was prepared during the 1988 ***Sirius*** Expedition for the Norfolk Island Government. The draft Plan was sent by the Norfolk Island Government to the Department of the Arts, Sport, the Environment, Tourism, and Territories. It was then circulated by that Department for comment, and the refined document is now being examined by both parties. The draft Plan, which is reproduced below, effectively represents the major part of the recommendations of the 1988 *Sirius* expedition.

A) HMS *Sirius* Draft Management Plan.

1. Introduction.

This document relates to the wreck of HMS ***Sirius***, the principal escort for the First Fleet convoy The ***Sirius*** had been built in 1780 for the Baltic trade, but purchased before completion by the British Navy, for use as a naval storeship. She was used in this role until her commissioning as a 6th Rate in 1787.

The vessel continued its role as protector when the First Fleet arrived at Port Jackson. A colony in the South Seas could not have been attempted had Britain not had a strong navy. The ***Sirius*** was the colony's representative of British naval power, and although her guns were not fired in anger, her presence was nevertheless important. For example, when the First Fleet arrived at Botany Bay the French Naval ships ***La Boussole*** and ***L'Astrolabe***, commanded by Monsieur de la Perouse, were in the area. Later, the British Government even considered sending her to round up the remaining ***Bounty*** mutineers.

The ***Sirius*** was given the role of provider to the colony. Governor Phillip's first problem was to ensure that his settlement would survive. Shortage of food was even more serious than lack of shelter. The soil was unproductive, and no provisions arrived from England. A flour and grain supply run by the ***Sirius*** to the Cape of Good Hope was the only means of avoiding starvation. Then at the beginning of March 1790, when food shortages were again a threat, the ***Sirius*** was used to take hungry mouths away from Port Jackson to Norfolk Island. At Norfolk Island the ***Sirius*** was wrecked, placing the colonies at Norfolk Island and Sydney Cove in great jeopardy.

The general location of the wreck was never forgotten. Anchors were raised in 1905 and 1973, and divers raised a variety of other material during the 1960s and 1970s. In 1982 staff from the commonwealth department responsible for the administration of the *Historic Shipwrecks Act, 1976*, the Department of Home Affairs and Environment, (now the Department of the Arts, Sport, the Environment, Tourism and Territories, or DASETT), proposed a bicentennial project to examine the ***Sirius*** wreck. The Australian Bicentennial Authority provided funds and administration for the project, which included fieldwork in 1983, 1985 and 1987. A further fieldwork season in 1988 was sponsored by British Airways, endorsed by the Australian Bicentennial Authority and administered by the Norfolk Island Government.

The wreck is protected under the *Historic Shipwrecks Act, 1976*. Under a Memorandum of Agreement the Norfolk Island Government has custody of artifacts recovered from the wreck site. The custody involves a responsibility to manage the collection, including exhibition, storage, conservation, provision of access to researchers, and provision of information to public enquirers. The Manager is the Administration of Norfolk Island.

The scope of the ***Sirius*** Management Plan includes the site, artifact collections, and a records collection.

1.1 The site is the area 150 to 300 metres east of Kingston Pier, extending south from the high reef a distance of approximately 200 metres to the concrete obelisk laid down in 1988. Artifacts are known to have been recovered from other locations within Sydney Bay, including an area to the west of the pier, and the inshore area east of the pier.

1.2 The artifact collections include the material recovered by the *Sirius* Project between 1983 and 1988, and now in the hands of the Norfolk Island Integrated Museums Programme (responsible to the Norfolk Island Government); the material on Norfolk Island recovered prior to the ***Sirius*** Project and now in the hands of the Norfolk Island Integrated Museums Programme; the material from the site now in the travelling exhibitions (in Australia) but due to be returned to the Norfolk Island Integrated Museums Programme at the conclusion of those exhibitions; and the material loaned by the Norfolk Island Government to the Australian National Maritime Museum.

1.3 The records collection includes approximately 2600 colour transparencies and 65 black and white films, mainly taken and catalogued by Patrick Baker of the Western Australian Museum.

2.Statement of Significance.

2.1 The site is of outstanding historical and archaeological significance. The wreck of HMS***Sirius*** is the only known remnant of the First Fleet. The surviving hull structural remains have the potential to provide information about the design and construction of the vessel, its maintenance and its condition at the time of the wreck. The nature and condition of the hull has a bearing upon the motivation of those responsible for sending the First Fleet. The site thus has research significance in relation to questions about the nature of the settlement and the intentions of the British in founding it.

2.2 The site, and the artifacts recovered from it, comprise a valuable source for comparisons with other European vessels employed in the South Seas during the latter half of the eighteenth century. Initial indications are that the similarities between ***Sirius, Bounty, Pandora, Endeavour, Resolution, La Boussole, L'Astrolabe*** and others are significant. Artifact collections exist from the ***Pandora, La Boussole, L'Astrolabe,*** and ***Bounty*** .

2.3 The ***Sirius*** site is important, despite its relatively poor condition, as a source of general information about eighteenth century European ship construction and fitting out, because few archaeological studies have been published on such vessels. Although archival sources for large line-of-battle ships of this period are relatively comprehensive, the same does not apply to the smaller vessels employed by the Navy.

2.4 The site has social significance because material has survived relating to the presence on board the ***Sirius*** of naval personnel, marines and convicts. This material has the potential to provide information about life on a British naval vessel during the eighteenth century, and information about the convict system.

2.5 The site has significance relating to military history. Military material found includes cannon, parts of small arms, and various shot.

2.6 The historical significance of the wreck is reflected in the responses to the loss of the ***Sirius*** both in Australia and on the Island. The letters, diaries and despatches of the period exhibit utter misery.
The loss of the vessel clearly had a great impact on the history of the Colony. On Norfolk Island the expanded population faced the immediate threat of starvation. Many would doubtless have suffered had not the weather dramatically improved for several days during the last week of March 1790, enabling the salvage of provisions from the ***Sirius.*** Martial law was proclaimed, and stores were desperately low for many months. The incident had a negative effect on Norfolk Island in the longer term as a colony - the wreck had highlighted the lack of any port facility. On mainland Australia the situation was just as bad. The mainland colony faced the danger of starvation. The small brig ***Supply*** was available, providing minimal protection for the colony and a tenuous link with the outside world, but it had little capacity to carry supplies. The loss of the ***Sirius*** had brought the entire experiment of a penal colony in New South Wales close to failure.

Study of the ***Sirius*** site may be expected to increase our understanding of the events occurring in New South Wales and on Norfolk Island during the first years of settlement.

2.7 The site has a symbolic significance in that the *Sirius* was the first 'Australian' shipwreck, in the sense of a ship being used by a people living in Australia. Only two other substantial vessels were wrecked in Australian waters during the later years of the 18th century, these being: HMS ***Pandora*** (1791), a vessel significant in the British invasion of the South Pacific, but not 'Australian' in the same sense as the ***Sirius*** ; and the *Sydney Cove* (1797), the first merchantman wrecked after settlement, but a vessel which had had no previous contact with the colony. The ***Sirius*** was the sixth known shipwreck in Australian waters, after the ***Trial*** (1622), ***Batavia*** (1629), ***Vergulde Draeck*** (1656), ***Zuytdorp*** (1712), and ***Zeewijk*** (1727).

2.8 The site has significance for studies of the process of wrecking. The comprehensive collection of documentary sources relating to the stages of disintegration, salvage activities, weather and sea conditions at the time provide the necessary information for the development of a model of the wreck process that can be tested on other sites and increase understanding of the process.

2.9 The ***Sirius*** site has significance for site environmental studies. Being in a different physical situation to the sites employed by British archaeologist Keith Muckelroy in generating his model of the relationship between site environment and site condition, the *Sirius* site may be regarded as an appropriate test of the model.

3.Conservation and Management Issues

3.1 The site and the artifact collection are of such significance that they must be protected at all cost.

3.2 Material recovered from the *Sirius* site includes that recovered by the *Sirius* Project in 1983, 1985, 1987 and 1988; that recovered by private divers prior to that time and passed on to the Norfolk Island Historical Society; that recovered by private divers and held in private collections on Norfolk Island and elsewhere; and that recovered by government instrumentalities prior to 1983 and now held in various collections in Australia and overseas.

3.3 The collection of material recovered from the site by the *Sirius* Project should be kept together with that derived from the Norfolk Island Historical Society as a collection on Norfolk Island. The only exception to this rule should be the limited number of items sent to other places, by the Manager after consultation with the Minister, DASETT, for a specified and limited time for purposes of exhibition, conservation, or analysis.

3.4 The photographic collection is presently stored in a satisfactory environment at the Western Australian Museum. The collection has been made accessible to all *bona fide* requests. Prints, duplicate transparencies and negatives have been, and will continue to be, produced for other users in the well equipped and full-time staffed photographic section.

3.5 Fabric and Setting. The site is located entirely underwater, but nevertheless has a monumental aspect as well as the archaeological one.

3.6 The visible elements of the site are highly susceptible to damage from natural forces. While vessels wrecked on a seabed composed of mud or other fine sediments, and in low energy environments, can be said to become moderately stable after an initial period of heavy deterioration, vessels (such as the *Sirius*) wrecked on a rock seabed in a high energy environment continue to deteriorate at a high rate even 200 years after foundering. Highly oxygenated water adds to the instability of the site. Corrosion potential measurements taken on iron artifacts in various positions on the site indicate that a very high level of corrosion is taking place on the site at all times. This corrosion leads to deterioration and disintegration of ferrous material left on the site.

3.7 Sea urchins cluster in crevices provided by artifacts on the site. It is clear that the urchins have caused and continue to cause widespread damage in the form of crater-shaped holes in iron artifacts, either through constant abrasion by spines or perhaps additionally through the action of some enzymic and digestive chemicals secreted by the organism. It is not feasible to prevent this form of erosion over the whole site, but urchin hollowing needs to be monitored where it affects fragile remains.

3.8 Heavy storms periodically occur at the site, and at these times current-borne rocks and pebbles may be expected to abraid, and to sweep away exposed artifacts. An indication of the forces operating on the site was given during the 1988 fieldwork when a half tonne pyramidal concrete plaque, lying in three metres of water, moved at least seven metres within three days of large swell conditions.

3.9 The visible elements of the site are also exposed to human intervention, notwithstanding the infrequency of visits by divers. During conditions of low swell dive-boats anchoring on the edge of the swell zone could unintentionally have their anchor interfere with the seaward side of the site, in particular the remaining ring of the first bower anchor thrown overboard by Captain Hunter. Once in the water, divers could unintentionally damage the site by removal of weed, by scraping objects with knives, or even by hanging on to or bumping into protruding artifacts during surge rushes. It is not anticapated that divers would remove large fixed artifacts, because it is generally known that the site is protected, and such protracted activities would attract attention. There are however small, loose artifacts such as sheathing tacks, shingle ballast and musket balls which could be removed surreptitiously by divers.

3.10 The site is not presently used for recreational activities, except on infrequent occasions. The principal reason is that most Norfolk Island diving (both by locals and tourists) is done in close association with the two dive shops, which provide equipment sale and hire, boat charter and diver training and supervision. Neither organisation takes divers to the ***Sirius*** site because the staff are of the opinion that sea conditions on the site are both uncomfortable and dangerous for most recreational divers. Most divers prefer the more attractive and comfortable deeper water further offshore. The presence (since 1988) of directional plaques adjacent to the site both above and below water will increase awareness of the exact location of the site and may lead to a limited increase in recreational use, which should be monitored in case of a need for facilities such as a mooring facility (divers generally approach the site from the sea), and signage warning of the danger involved for unsupervised divers.

3.11 The principal archaeological deposit lies within 150 metres of Kingston Pier, the principal means for launching and landing of vessels and seaborne cargo. There are no current plans for extension to the pier, and if such plans should arise it is likely that they would impact more upon the area to the west than to the east.

3.12 There is a need for continued archaeological investigations on the site to answer important questions about the ship which in turn have a bearing upon the debate about the original British motivation for colonisation of Australia.

3.13 Excavation on some parts of the site may be expected to cause some damage to remaining artifacts through additional exposure to the elements.

3.14 The public should be told of the significance of the place. There is a strong need for the site to be interpreted, given the important role played by the ***Sirius*** in the colonisation of Australia, and the relative inaccessibility of the site itself, lying entirely underwater and situated in such a hostile environment. There is a need to heighten public awareness of the existence of the wreck at Norfolk Island and the reasons for it being there, to familiarise the public with the debate about the British motivation for colonisation and the ways in which the ***Sirius*** site can influence that debate, and to develop public awareness of the important role of Norfolk Island in the initial colonisation plan.

3.15 The possibilities for interpretation of the site are very substantial. The collection of artifacts recovered from the ***Sirius*** includes items relating to the hull, the fittings and armament, and the people who worked and lived on the ship. These artifacts have the potential for interpretation of many of the themes relating to the significance of the site. A number of historic buildings have been restored at Kingston, and a recent study recommended that one of these, the Prince Philip Youth Centre, be made available for the display of material recovered from the ***Sirius*** . That building is located not far from the ***Sirius*** site, and has sufficient floor space for appropriate interpretation of the site. Arrangements should be made by the Manager for annual inspection and maintenance of the two information plaques indicating the wreck site position.

3.16 The site is protected under the Commonwealth's *Historic Shipwrecks Act, 1976.* DASETT has the responsibility for the administration of the Act, and it is necessary for visitors to the site to obtain a permit to do other than a non-interference dive on the site. DASETT can delegate certain powers under the Act to State bodies.

3.17 Custody of artifacts recovered from the site is with the Norfolk Island Government under the Memorandum of Understanding between the Commonwealth Government and the Norfolk Island Government.

3.18 The ***Sirius*** Project expedition leader was required to provide a full archaeological report to the Australian Bicentennial Authority, The Government of Norfolk Island and DASETT, by October 1989. The report, to which a number of the expedition members contributed, was required to include full details of the work carried out since 1982 as part of the ***Sirius*** Project and provide considered conclusions about the archaeology of HMS ***Sirius*** .

4. Conservation and Management Policy.

4.1 The provisions of the *Historic Shipwrecks Act, 1976* will continue to apply to the site and collection.

4.2 Developments in the area (such as pier extensions) will be planned such as not to impinge on the ***Sirius*** site. This applies particularly to the principal deposit to the east of the pier.

4.3 Use. The underwater site will generally be reserved for passive recreation. Signage will be maintained both below and above water.

4.4 All steps necessary will be taken to protect the site from damage from boating and recreational activities.

4.5 The effects of sea urchin hollowing will be monitored on the site, and if necessary control methods may be instigated in the areas of heavy iron concretions.

4.6 Interpretation. An interpretive centre will be located in the Prince Philip Youth Centre building at Kingston close to the wreck site. The interpretive centre will exhibit artifacts recovered from the wreck in conjunction with introduced interpretive material to explain the role of the ***Sirius*** in the colonisation process.

4.7 To increase public awareness of the site, encouragement will be given for the production and availability of pamphletts and other interpretive materials, including books, audio visuals and videos.

4.8 Arrangements will be made for the site and collection to be inspected regularly by appropriate specialists who will take the necessary procedures for site conservation.

4.9 No permit will be given for purposes of conservation or for archaeological expeditions to work on the wreck site unless that permit is consistent with the ICOMOS Burra Charter, and has the approval of both DASETT and of the Norfolk Island Government. Given the site's outstanding archaeological significance it will be disturbed only for essential and justified conservation or research purposes by qualified and approved conservators or archaeologists. Where research questions can be answered by recourse to alternative sites the ***Sirius*** site will be left undisturbed as a permanent reference area.

4.10 Material recovered from or associated with the ***Sirius*** shall be conserved, housed and curated in a professional manner which ensures;

a) its long term conservation and protection,
b) its consistent and comprehensive documentation to ruling museum standards,
c) its adequate storage, as far as possible in one location,
d) the adequate display to the public of parts of the collection,
e) its access to *bona fide* researchers.

As part of this policy, the private, and other government holders of *Sirius* material, will be encouraged to pass this material on to the museum

4.11 All steps necessary will be taken to protect the site from damage from boating and recreational activities.

5. Implementation Plan

5.1 The Norfolk Island Government, in consultation with the Commonwealth Government, will encourage the production and availability of pamphlets and other interpretive materials, including books, audio visuals, and videos, to increase public awareness of the site, and of the role played by the ***Sirius*** in the colonisation of Australia, and more specifically of Norfolk Island. When the full archaeological report on the wreck is received by the Norfolk Island Government in October 1989, that Government will consider encouraging or facilitating the production of a revised version of the book ***HMS Sirius*** *Past and Present* .

5.2 Arrangements will be made between the Commonwealth and Norfolk Island Governments for an inspection visit to the *Sirius* site and collection once every year by a maritime archaeologist acquainted with the site and collection. The inspection will be followed by a condition report. The Curator will provide a half-yearly report on the condition of the site and collection according to a format to be specified by the leader of the ***Sirius*** Project expeditions.

5.3 Arrangements will be made between the Commonwealth and Norfolk Island Governments for similar visits and reports by a conservator with expertise on underwater archaeological materials. The Curator will likewise provide half-yearly reports to a format specified by the Conservator of the ***Sirius*** Project. A sacrificial anode, placed on the remaining carronade on the site by the 1988 ***Sirius*** expedition, will be monitored on those occasions by the visiting conservator. The Norfolk Island Government will arrange for local divers to inspect the sacrificial anode once every six months.

5.4 Arrangements will be made between the Commonwealth and the Norfolk Island Governments for the recovery and treatment, by a maritime archaeologist and conservator, of the remaining carronade from the site. This should be done because of its vulnerability on the seabed. The appropriate timing would be soon after the successful completion of treatment of the first recovered carronade, such that information gleaned during that treatment can be put to good effect.

5.5 The Manager will, when the *Sirius* Museum is opened on Norfolk Island, encourage private and government holders of *Sirius* material to pass this material on to the Manager's custody.

5.6 The pamphlets to be available at the *Sirius* Museum on Norfolk Island will ask divers not to anchor boats inshore of the underwater information plaque, which will be placed seaward of the concreted ring of the anchor recovered in 1973. This measure will help to avoid damage to the site from boat anchors and chain. The pamphlets will point out that divers should not physically interfere with the site. Board riders will not be restricted in their access.

5.7 The Manager will facilitate the maintenance of a register, initiated by the *Sirius* Project, of all material recovered from the *Sirius* site.

5.8 The Manager will ensure that records are kept of all work done on the collection for purposes of conservation, research and display.

5.9 The Manager will ensure that all material in the*Sirius* collection is conserved and preserved according to the guidelines and code of ethics of the AICCM (Australian Institute for the Conservation of Cultural Materials Inc) as prescribed by the Western Australian Museum to the present time.

5.10 All artifacts will be housed indoors in the Prince Philip Youth Centre building, unless a building of superior quality is made available close to the wreck site.

5.11 All but large iron artifacts will be housed in temperature and humidity controlled storage and display cabinets. Such control can be achieved through passive environmental management strategies associated with the construction of 'sealed' display cases. The storage cabinets will be 'Perth Cabinets' (manufactured by Bristek metal division, 387 Scarborough Beach Rd, Osborne Park W.A.) or a similar product. The display cases will be of the 'Click System' (Click Systems, 7 Cato St, Hawthorn East, Victoria) or a similar product.

5.12 Cabinets will have provision for locking.

5.13 As far as possible all *Sirius* material will be stored in the one location.

5.14 The Norfolk Island Government will ensure that the Prince Philip Youth Centre building, at Kingston close to the location of the wreck site, is made available. A controlled micro environment, in the form of temperature and humidity controlled storage and display cabinets, will be provided for the *Sirius* artifacts.

5.15 The Norfolk Island Government will ensure that a selection of the artifacts is utilised for a display that will illuminate the role of the *Sirius* in the foundation of the first settlements at Sydney Cove and Kingston.

5.16 The Manager will ensure that supervised access is provided, in the front storeroom or kitchen of the Prince Philip Youth Centre building, to *bona fide* researchers who apply in writing, and will keep a register of those researchers.

5.17 *Sirius* objects on display will be given the security of glass or other barriers, and the building will be provided with fire and burglar alarms. Staff will attend the building, and it will be open to the public at least three days each week at regular times, as well as at appointed times for bus tours.

5.18 The copyright of the *Sirius* photographic collection belongs to the Australian Bicentennial Authority (the pre 1988 section) and the Norfolk Island Integrated Museums Programme (the 1988 section). In addition, photographs have been taken of artifacts temporarily held for conservation treatment at the Western Australian Museum. These photographs will be catalogued by Patrick Baker and stored with the main ***Sirius*** photographic collection. All photographic originals will later be stored as a unified collection (in cabinets as advised by Patrick Baker) in the strongroom of the New Military Barracks on Norfolk Island. The Norfolk Island Government will facilitate the production of duplicates as required for lecturing and publication purposes. Duplicates will be produced at cost at the Western Australian Museum such that one set of duplicates can be held in Western Australia and one set on Norfolk Island.

Vulnerability to damage (specially by damp, fungus, heat and light) makes it essential that particular care be given to the storage of photographic originals. For lecturing and publication purposes duplicates will be used as much as possible, to reduce the risk of mechanical damage.

Until the archaeological and conservation research work (Henderson, Stanbury and MacLeod) is completed (the current schedule is for completion by October 1989) the photographic collection will remain at the Western Australian Museum.

5.19 DASETT will arrange, through the Norfolk Island Government, for the signing-on of inspectors, drawn from divers drawn from the local diving community and given some previous instruction, to check the site's security.

6. Review.

The Management Plan will be reviewed in 1993 by the Norfolk Island Government in concert with DASETT, the Western Australian Museum, local divers and all others interested in the site.

B) Completion of Site Work Relating to the 1988 Research Design.

The Research Design developed for the expedition to the ***Sirius*** wreck in 1988, and the excavation permit relating to that expedition, envisaged cutting a transect through the most appropriate part of the ballast mound, to find evidence of the hull. Because of insufficient time during the 1988 expedition the transect was not undertaken, and important questions raised in the Research Design remain unresolved. Plans should be drawn up for an expedition to carry out that work.

APPENDICES

Appendix 1

'...lost in the *Sirius* ...?' Consideration of the provenance of the hatchet head recovered from the *Sirius* wreck site, Norfolk Island.

Isabel McBryde, Australian National University, and Alan Watchman, Canberra College of Advanced Education.

Draft for the publication - not to be quoted without the author's permission. Note: The figures will appear with the article in *Records of the Australian Museum*

Abstract

In Graeme Henderson's excavation of the ***Sirius*** wreck off Norfolk Island a ground stone hatchet head was recovered. This paper explores the problems of establishing its ultimate origins, its cultural context and its historical significance.

An intriguing find from the recent underwater excavation of the ***Sirius*** wreck off Sydney Bay, Norfolk Island, was a stone hatchet head (SI 479). Its distinct form, size and raw material caught the eye of a diver working amongst the flint pebble ballast of Area I of the site. How did this stone artefact become part of the archaeology of a late eighteenth century shipwreck on an island then uninhabited? What were its origins? How did it come to be on board ***Sirius*** in March 1790? Should we accept without question that it was on board ***Sirius*** at that time? These and many other queries came to mind on examining this simple stone artefact when the excavation's director, Graeme Henderson sent it to one of us (McBryde) for comment in mid 1987 (Figure 1). It would have intrigued Fred McCarthy with his lifelong interest in stone artefacts, in their raw materials and in exchange systems. He also spent many years studying the culture of Aboriginal groups of the Sydney District and the archaeology of sites near the Nepean and Hawkesbury. These themes are all relevant to the puzzle of this artefact's provenance; so it seemed a fitting topic for a volume which honours his contributions to Aboriginal studies.

The major questions raised by this hatchet head relate to its ultimate provenance and cultural context. Several options may be considered:

1. Given the find spot (associated with flint pebble ballast from the wreck of an English naval vessel recently re-fitted and ballasted in the Thames) the artefact could be a British Neolithic axe head which had become incorporated in Thames flint gravels.
2. The artefact could be Australian, an Aboriginal hatchet head, acquired by one of the ship's officers for his collection of 'artefactual curiosities' or alternatively the possession of an Aboriginal person from Sydney travelling on the ship.
3. Another possibility is that it was taken on board at Sydney unintentionally. ***Sirius*** was refitted there in 1789 and the 90 tons of shingle ballast was presumably dumped in a heap on the nearest shore. The shovellers returning the shingle ballast to the hold are unlikely to have noticed or cared if some local 'pebbles' went in with the shingle and (given that several guns were left off at Sydney, thus lightening the ship) they may even have been ordered to add to the shingle ballast with local stone. Testing of this hypothesis must await assessment of the stone ballast on the site, most of which has not been raised.
4. The artefact could have been part of an officer's collection, but acquired in South Africa, India or South-East Asia, particularly Java. Many ships travelling to and from Australia called at the great trading centres of Asia and the Dutch East Indies, while the Cape was a major source of grain and livestock for the settlement at Port Jackson. At the end of 1788 the ***Sirius*** voyaged there to acquire urgently needed supplies.

5. The artefact could be Polynesian, lost off-shore from a Polynesian canoe, or archaeological witness to an earlier wreck. Its incorporation in the wreckage of the ***Sirius*** on the high energy shoreline of Sydney Bay could be purely co-incidental. Sydney Bay is a likely landing place for any voyager; Polynesian artefacts and the bones of Polynesian rats have been found at nearby Emily Bay in recent archaeological studies (Specht, 1984; Irwin, 1989). In the late eighteenth century stone adzes were uncovered in the agricultural activities of the first settlement (King, 1791, 1792 and 1793).

To test these various hypotheses, and so arrive at an explanation of this artefact and its presence on board *Sirius* , we must look to evidence provided by the history of the Port Jackson settlement and of the *Sirius* herself, as well as the artefact's intrinsic and extrinsic attributes, particularly the petrology of its raw material.

Examination of a Non-Australian Origin

To consider first the question of an English derivation.

Could the artefact be of English Neolithic origin, incorporated in the Thames' prehistoric stone gravels, and so ultimately the ship's stone ballast? Certainly it would not be the first British prehistoric stone implement to reach a distant location and confuse archaeologists. However, its features are not those of a British axe-head of hard-rock, such as artefacts from the Langdale quarry or from Cornwall. Further it is not made of quarried rock but from a water worn cobble.

The ***Sirius*** carried iron, shingle and coal ballast. Her iron ballast was in the form of blocks, weighing about 152 kg, laid down in the main hold before the shingle was set in place (in this case flint pebbles) followed by the coal. This ballast was all newly set in place after the ship's refit in 1786/7. So she was not carrying remnants of ballast acquired on previous voyages. Considerable quantities of iron ballast and of flint pebbles were discovered in the excavation of the wreck site, including a substantial mound of iron blocks in Area 12 and the flint pebbles in Areas 1, 2 and 3 (see Henderson and Stanbury, 1988:Ch.9). Had the artefact's features been consistent with a British origin its discovery in an area where ballast was concentrated could be seen as supporting this interpretation. Other materials associated with the hatchet head and the ballast were lead shot, together with bronze and copper pieces from the exterior of the lower hull.

Arguments for an Indian, Asian or African provenance must be tested against opportunity for ships' officers to acquire such items, as well as against archaeological attributes, including petrology. In her last voyages the ***Sirius*** had visited only Tenerife, Rio and Cape Town. A copper two maravedi coin, dated 1774 and bearing the head of Charles III of Spain, was found on the site in 1988. It may have been acquired in Tenerife. So the possibilities are narrowed unless one of her officers had with him collections made on previous voyages, or acquired from someone on another ship recently arrived from other regions. Given that the ***Sirius*** was wrecked early in the settlement's history such opportunities are very limited indeed. The features of the artefact do not suggest an Indian or Indonesian provenance, though there might be some similar petrologies in the hinterlands of Goa. The lithologies of the regions behind Bombay or Madras are quite dissimilar to the pelitic hornfels of the ***Sirius*** specimen. However, ***Sirius*** did visit the Cape. Her voyage there at the end of 1788 to obtain supplies was her last before sailing for Norfolk Island. The intervening months were spent in Port Jackson undergoing a much needed overhaul. Archaeological specimens of edge ground pebbles might have been available in Cape Town, as they do occur in the Wilton related industries of Southern Africa. However, they are rare in these assemblages compared with more fully polished axe-heads (Sampson, 1975:337,418,425). That they occur in archaeological deposits of some antiquity, and then only rarely, makes them rather unlikely curios to be waiting avid collectors in the Cape Town of 1787/1788. They were not part of eighteenth century material culture.

Discussion so far assumes that the artefact derives from the March 1790 shipwreck, that it was on board ***Sirius*** when she struck the reef. This assumption could well be challenged. The coastline of Norfolk Island around Sydney Bay is one of high energy, movement of the ***Sirius*** between March 1790 and February 1792 is well documented, while there has been considerable dispersal of her timbers and contents since then (see Figure 2). Items lost at sea before or after the wreck could well be associated with material from *Sirius*. However, the particular location of the *Sirius* wreck site is obviously dangerous and mariners would have avoided it normally. The landing place as some 250 m westward.

Polynesian artefacts and faunal remains, recovered from archaeological contexts dated to c.900/1000 AD, near Emily Bay not far from the *Sirius* wreck site, bear witness to earlier voyages. These have been investigated by Specht (1984; see also Irwin, 1989). The sinking of a canoe or casual losses could well have left a Polynesian adze on the sands or corals of the bay, later to become mixed with the material from the *Sirius* wreck. King, the settlement's commander, noting the presence of stone artefacts on the island, was intrigued by the implications of earlier settlement, and reported to Sir Joseph Banks (King, 1791, 1792 and 1793; see also Collins, 1798:184). In 1792 he sent a 'stone axe' to Banks, its exact provenance uncertain but found by a 'reliable person'. Later arrivals could also have carried Polynesian stone artefacts to Sydney Bay; King brought some Maoris from New Zealand in 1792 to instruct the convicts in the arts of flax weaving. These male Polynesians little versed in such arts were soon returned home. However, the attributes of the *Sirius* artefact differ substantially from those of Polynesian adzes known archaeologically or from eighteenth century collections (Shawcross, 1970; Shawcross and Terrell, 1966). The hypothesis of Polynesian origin, and the artefacts pre-dating the *Sirius* wreck must be rejected.

Examination of Evidence for an Australian Origin

Absence of positive evidence to sustain arguments for a non-Australian origin for the artefact leads us to examine those for an Australian provenance. We should then also ask how a non-European artefact came to be on the *Sirius*. To whom did it belong? How had it been acquired? Historical, archaeological and petrological perspectives may suggest some answers.

Assuming for the moment that the artefact is Australian (an Aboriginal hatchet head) let us explore the question of how it came to be on *Sirius* when she struck the reef in Sydney Bay. The hatchet with its stone head was a vital part of an Aboriginal man's equipment for daily use, carried with his spears, spear thrower and club. Does the presence of this piece of equipment then signal an Aboriginal presence on *Sirius* ? Certainly we have records of Aborigines visiting Norfolk Island: Bennelong and Bondel in 1791 (Collins, 1798, I:177). Bennelong went again in April 1796, as did another, but un-named, 'New Hollander'. The island's Victualling Books are our only record of these later visits. However, the letters of Chapman, King's assistant, give us more details of Bennelong's 1791 visit. He had to take charge of the excessive baggage.

> ...one of the natives has taken a fancy to go with us to Norfolk Island and yesterday morning brought all his spears and fish-gig, stone hatchet, bones for pointing his spears and his basket to be packed up for him. The governor is to give him two Nankeen dresses and white shirts and a trunk to keep [them] in which pleased him very much his name is Bennelong he is a very well behaved man he drank tea and supped with us last night at the governors. (Chapman, 1791:18-19)

So Aborigines did travel to Norfolk Island on English vessels, taking their equipment with them, including stone hatchets. But all recorded instances post-date the wreck of the *Sirius*. The *Sirius'* crew list does not mention any Aborigines being on board during the voyage to Norfolk Island.

Was the '*Sirius* hatchet' then carried not as part of Aboriginal equipment, but in a collection of native weapons made by one of her officers? The ships' officers and 'gentlemen' of the First Fleet were avid collectors of natural history specimens and 'artificial curiosities' (McBryde, 1989). When the artefact was located in the excavation it was not associated with the material from the stern cabins which would have housed the senior officers, those most likely to have such collections. However, this could be accounted for by underwater movement of material across the site over time, while many personal items would have been disturbed during the long period of salvage and scavenging before *Sirius* finally broke up (see Figure 2). Of the First Fleet officers who have left us clear records of their collecting activities (Ralph Clark, Watkin Tench, Arthur Bowes Smyth, Newton Fowell, John White and Arthur Phillip himself) only Newton Fowell was on the *Sirius* in March 1790. He wrote to his father that in the wreck he lost documents and maps, as well as 'a very Valuable Selection of Birds which cost me a great deal of Trouble' (Fowell, 1790, in Irvine, 1988:131).

Other officers and crew members may well have held collections, including Aboriginal artefacts. As early as October 1788 Phillip had to take strong measures to deter the stealing of Aboriginal weapons and tools to meet the demand from collectors among the crews of fleet transports and of passing vessels (*HR NSW* 1. ii:208; Phillip, 1789:139-140). The loss of artefacts caused continuing resentment among the Aborigines of Port Jackson:

> ...the convicts were everywhere straggling about, collecting animals and gum to sell to the people of the transports, who at the same time were procuring spears, shields, swords, fishing-lines, and other articles from the natives, to carry to Europe; the loss of which must have been attended with many inconveniences to the owners. (Collins, 1798:13)

There were probably several such collections in the officers' quarters of the ***Sirius***. The long stay in Port Jackson for repairs after the voyage to Cape Town increased opportunities for their acquisition. Testing against available historical evidence we certainly cannot reject the hypothesis that our artefact was part of such a collection, acquired by an officer in some personal exchange with a Port Jackson Aborigine (Figure 3).

So there are acceptable historical explanations for the presence in ***Sirius*** of an Australian hatchet head from the Sydney district. Can we take this further than historical probability? Do the features of the artefact itself provide additional clues? How does its attributes match up against those of other Australian examples? We shall look at its dimensional, formal and functional features as well as the petrology of its raw material, which could well be the decisive attribute.

Comparison with Relevant Collections

The hatchet head is made on a cobble preform which has been given minimal modification (see Figure 1). The removal of a few flakes from one surface has shaped the butt and the bevelled working edge is clearly ground. Manufacturing striations are still visible. This grinding extends back from the cutting edge into the second quarter of the artefact's length. The edge is slightly curved in plan shape, has an edge angle of 78° and shows some edge damage (abrasion and tiny flake scars). Symmetrical in profile it displays a slight skew in plan view which may indicate re-sharpening at some stage in its use-life. The butt is slightly curved. In section the artefact is an irregular flattened oval, the shape of the original cobble. Its dimensions are:

Length	11.4 cm
Width	7.6 cm
Thickness	3.5 cm

Pitting on one surface indicates hammer or anvil use, and the artefact also bears traces of a resinous material, probably the medium used to retain the wooden haft. These have been analysed and reported on by David Kelly of the Western Australian Museum (Henderson and Stanbury, 1988:144). The raw material is a spotted pelitic hornfels; its specific characteristics are discussed in detail below.

Is this combination of attributes sufficient to identify the artefact as Australian? Could one further say they are characteristic of hatchet heads from the Sydney district? Is there a distinct aggregate of features specific to the Sydney District? The ***Sirius*** artefact is a very unelaborate piece; the modification of the natural cobble preform is functionally oriented, confined to creating the bevelled edge and shaping the butt. The cobble has been selected to meet the needs of size, shape, weight and balance. The artefact lacks stylistic features that could be interpreted as distinctive, that might be indicative of regional or local conventions. Its attributes could well be functionally determined, of a kind duplicated whenever and wherever that combination of particular edge shape and angle, with body size, weight and form, is needed for a specific range of cutting or chopping tasks. Such edge ground pebbles, like the unifacially flaked pebble chopping tools, constitute a difficult category of artefact with which to play the games of provenance allocation, whether geographical or cultural. However, as with the flaked pebbles, within the broad similarities there may be some minor discriminating features, so comparisons could be useful. They may, of course, only indicate that the *Sirius* artefact falls within a locally preferred range of features and not suggest any certain provenance.

To assist comparison some general features of edge ground artefacts from locations in south-east Australia are presented here. The choice of pebbles or cobbles as convenient preform is prevalent in many coastal localities of eastern Australia, especially in northern New South Wales and eastern Victoria, so collections are chosen from these areas as well as the Sydney Basin.

For interest we list below the dimensions of two inland assemblages (one from Victoria and one from New South Wales) in which ground artefacts made of quarried stone dominate, most of them shaped by bifacial flaking of a core or thick flake preform. These artefacts are consistently smaller than the coastal pebble ones.

	Albacutya (Vic) n = 35	**Combaning** (NSW) n = 36
Mean length	9.72	11.5
Standard deviation	2.05	2.98
Range	6.0-13.6	7.0-17.2
Mean width	7.02	6.9
Standard deviation	0.81	1.4
Range	5.3-8.4	4.6-10.2
Mean thickness	3.47	3.9
Standard deviation	0.77	1.28
Range	2.0-4.9	2.2-8.6

Comparing one specimen with assemblages calls for caution, the more so when the artefacts concerned are poorly differentiated and share many attributes. However, there are characteristics of the collections of ground-edge artefacts which may distinguish those of the Sydney Basin from collections of north-eastern New South Wales. These latter are larger, are more extensively shaped by flaking before the edge is ground while the grinding extends over more of the blade's length than is usual for hatchet heads made on pebble preforms in the Sydney Basin. Certainly the ***Sirius*** artefact falls easily within the range of attributes commonly represented among collections from Emu Plains/Richmond and the Sydney District. However, one could not claim that it shows features found <u>only</u> on artefacts from the Sydney Basin, nor that its features are absent from artefacts of north-eastern New South Wales or south-eastern Victoria.

Historical and Field Evidence from Emu Plains/Richmond

If the artefact's dimensional and formal characteristics are consistent with a Sydney District or Richmond provenance is there any way of testing this further? Could its raw material be specific to a particular location? The spotted pelitic hornfels of which the **Sirius** hatchet head was made is often referred to in early geological literature for the Sydney Basin as 'spotted altered claystone' (Dickson, pers. comm.) and it is noted as a common raw material for ground edge artefacts (Liversidge, 1894). Such rocks do not outcrop in the Sydney Basin itself, but they are found as cobbles in river gravels on its western margins, for example, those of the Nepean/Hawkesbury system between Emu Plains and Richmond (Ross, 1976). They presumably derive from volcanic contexts in the mountains to the west. The gravels in which they occur may derive from geological contexts of considerable antiquity, pre-dating present river systems. Liversidge commented (1894:233):

> The pebbles of spotted altered claystone, from which many of the weapons have been made, were probably brought from the old river bed cut by the road and railway at Lapstone Hill, Emu Plains; the source of this rock is not known.

Historical evidence may be relevant here. In the first decade of European settlement exploration centred on the Hawkesbury to map the land beyond Rose Hill and locate desperately needed arable land. For the expeditions of April and May 1791 Richmond Hill (see Figure 4) was a focal point, both as a readily identified land mark and as the upper limit of tidal effect in the river. It was also of easy access by boat from Broken Bay. Hunter's exploration of 1789 reached this point, where, as Bradley records:

> ...they got into very shoal water with very large hard stones (of which the Natives make their hatchets etc) and at the beginning of the falls, they found themselves at the foot of a hill which they ascended... the Governor named it Richmond Hill (Bradley - *Journal* -July 1789, 1969:170).

From reports of the 1791 exploration (Hunter, 1793:519-20; cf. Tench 1961:228 and 234) we learn that in April Phillip and his party met with a group of Aborigines. Colebe and Balloderree, their Aboriginal guides, questioned one old man and from his answers respecting the river '... concluded they had come this journey in order to procure stone hatchets from that part of the river near Richmond Hill....' Parting from this group Phillip was given two stone hatchets and other implements; he reciprocated with gifts of bread, fish hooks and two small metal hatchets. The Aborigines were said to belong to an inland group distinct from the coastal clans, but the incident suggests that linguistic communication was relatively easy in spite of tensions between coastal people and these 'climbers of trees' who lived by hunting. This evidence would give historical support to arguments in favour of a source for the ***Sirius*** artefact's raw material in the Nepean gravel beds near Richmond Hill.

These arguments needed testing in the field. So we visited the Emu Plains/Richmond area to ascertain whether cobble beds still existed in that stretch of the Nepean, and whether they contained spotted pelitic hornfels with the characteristics of that from which the ***Sirius*** artefact was made. We examined and sampled the cobble beds exposed along the Nepean at three locations - near Richmond Hill, at the confluence of the Grose and at Emu Plains (see Figures 4,5,6 and 7). These locations provided samples from the northern and southern extremes of the area indicated as significant by the historical sources and by the archaeological work of McCarthy, Kohen and Stockton. It also seemed important to check at the confluence of the Grose, a major stream whose gravels could well contain relevant lithologies. Shaws Creek, to the south, seemed unlikely to be an important source as most of its gravels derive from sandstone areas (Kohen, Stockton and Williams, 1981; Kohen, Williams and Stockton, 1984). The Nepean beds contain both pebbles and cobbles, ranging in size from four centimetres to thirty-eight centimetres. They include relevant material in terms of both the lithologies represented, and the shape and size of the cobbles. No evidence of artefact manufacture was noted in the immediate vicinity of the area sampled. Given the changes in the local environment and in stream flow over the last two hundred years this would not be unexpected. However, extensive exposures of stone working sites were recorded by McCarthy in the 'thirties, four near Emu Plains and one at Castlereagh where knapping evidence was found along both banks of the river for nearly a kilometre (McCarthy, 1948) (see Figure 4). Large cobble beds were noted in the river at this point. In the same area McCarthy recorded an extensive complex of grinding grooves on sandstone outcrops in the river bed (see b on Figure 4). Recently rock shelters at Shaws Creek near its confluence with Nepean at Castlereagh have been investigated by Kohen (Kohen, Stockton and Williams, 1981; Kohen, Williams and Stockton, 1984) (d on Figure 4). These are not far from the area discussed by McCarthy (b/c on Figure 4). Edge-ground artefacts were recovered in the excavation, identified as basalts.

Other recent investigations in the Emu Plains/Richmond area have concentrated on the Cranebrook Terraces (see Figure 4) north of the river at Emu Plains. The major concern in this study has been the Pleistocene chronology of the gravels, and the possibility that they incorporate very early artefactual material (Nanson, Young and Stockton, 1987). A discussion of the evidence from the Nepean gravels in relation to the petrology of the ***Sirius*** artefact follows.

Petrology of the hatchet-head

In hand specimen the hatchet-head is dark green to black, very fine-grained and weakly layered. Petrologically the rock from which the artefact was made is a fine-grained spotted pelitic hornfels, characterised by small clots, predominantly or cordierite, which are not evident on the dark broken surface. The cordierite-rich spots are up to 0.5 mm across and form at least 40% of the rock. Dust-like aggregates of red and brown rutile and spinel are enclosed within the cordierite clots. Flakes of colourless muscovite and green biotite and chlorite are randomly dispersed between the cordierite clots. Small sub-angular quartz clasts, less than 0.3 mm in diameter, are disseminated throughout the rock and indicate its previous sedimentary origin. Slivers and fine granular clusters of magnetite occur in accessory amounts. The hardness of the stone is attributed to the fine grain size and to the strong fabric; it is a product of the recrystallisation of the pre-existing clay minerals in the sedimentary rock.

Based on the mineralogy of the hatchet head and assessing the variability of elemental abundance and mineralogy found in pelitic hornfelses (Joyce, 1970) the cobble, from which the artefact was fashioned, was eroded out of rocks located in the outer parts of a contact metamorphic aureole.

Possible source rocks

Fine-grained pelitic hornfelses do not crop out in the vicinity of Sydney Cove, where the ***Sirius*** anchored, nor on the North Shore where she underwent lengthy repairs, but they are found at Hartley (near Lithgow), and in the gravels in the Cranebrook Terrace of the Nepean River (see Figure 4). To the south of Hartley, in the valley of the Cox's River (which flows into the Nepean-Hawkesbury River system south of Emu Plains), basic igneous rocks intrude the Bathurst Batholith and surrounding rocks (Vallance, 1969:191). Cordierite-quartz-biotite hornfelses are abundant in the aureole rocks of the Bathurst Batholith (Joplin, 1973:42).

The Cranebrook Terrace was formed largely during an episode of exceptional fluvial activity in the Wollondilly-Nepean Basin prior to the last glacial maximum (Nanson, Young and Stockton, 1987). Cobbles and pebbles were transported from hinterland sources, most probably down the Cox's River, and deposited over a braid plain close to the Nepean Gorge by a river with a much greater and more variable flow rate than the present Nepean River. Thick basal gravels were deposited until about 40,000 years ago when the flow regime changed and the river became laterally very stable (Nanson, Young and Stockton, 1987).

Pyroxene gabbro and granite porphyry cobbles, similar to those in the intrusive bodies near the Cox's River, dominate the gravel beds along the Nepean-Hawkesbury Rivers. Various pelitic hornfelses also make up a substantial proportion of the rock types in the gravels; these are most probably derived from the aureole of the Bathurst Batholith.

In addition to pelitic hornfelses, rock types found in the gravels on the Terrace include rhyolite, brown chert, dacite, quartzite, ignimbrite and siliceous mudstone (Nanson, Young and Stockton, 1987). Samples of pelitic hornfels collected from the Terrace below the weir on the Nepean River, west of Penrith (location 3 on Figure 4 - see also Figure 7) at the confluence of the Grose and Nepean Rivers (location 2 on Figure 4, see also Figure 6) and from 'Belmont Park' on the river just south of Richmond Hill (location 1 on Figure 4 - see also Figure 5) were petrologically examined and compared with the hatchet head from the ***Sirius***.

Petrology of pelitic hornfels from gravels along the Nepean-Hawkesbury

Spotted quartz-cordierite-biotite-magnetite-graphite hornfelses in the gravels below the weir near Penrith (location 3 on Figure 4) have a distinct grey brown cortex with small indentations where the underlying mineral clots have been preferentially weathered. Broken surfaces are dark green to black but the spots are not usually visible until examined under a microscope. Contact metamorphism of carbonaceous silty shale formed the ovoid shaped clots of cordierite. Sieved through the clots are small flakes of biotite and graphite and granular magnetite. Small flakes of brown green biotite are also developed in clusters between the cordierite clots. Anhedral magnetite grains are scattered evenly throughout the rock. Graphite flakes are less then 0.1 mm in diameter and are concentrated near cleavage and strain planes.

At the confluence of the Grose and Nepean Rivers, (location 2 on Figure 4) the spotted pelitic hornfels contains cordierite, chlorite, muscovite, quartz and magnetite. Clots of cordierite also contain accumulations of fine-grained magnetite crystals and are bounded by flakes of green brown chlorite.

Further downstream on the Hawkesbury River, near 'Belmont Park' below Richmond Hill (location 1 on Figure 4) the dark spotted pelitic hornfels looks most like the ***Sirius*** hatchet head. It is composed of intergrowths of biotite and muscovite flakes and opaque minerals developed within cordierite porphyroblasts. The matrix of the rock is characterised by quartz, muscovite and biotite. Accessory magnetite is randomly scattered through the rock as equant euhedral crystals. The degree of contact metamorphism shown by the excellent habit of magnetite crystals is slightly higher than that of the other gravel specimens and of marginally higher grade than the ***Sirius*** axe-stone.

Discussion of the Petrological Evidence

The petrology of the spotted pelitic hornfelses examined from the gravels between Penrith and Richmond do not precisely match the texture and mineralogy of the ***Sirius*** artefact. The differences are both textural and mineralogical. The size, shape and composition of the clots, though similar in all specimens, are not identical to those of the ***Sirius*** hatchet. Accessory rutile and spinel are developed in the cordierite clots, and the ***Sirius*** hatchet contains small amounts of sub-angular quartz clasts. Though the comparison is not exact the samples share similar geological environments of formation and they may therefore all be derived from the same general proximity in the Cox's River valley, which is the nearest probable source.

An exact likeness between the ***Sirius*** artefact and the pelitic hornfels in the gravels is not expected because of the limited sampling from the extensive deposits of gravel and as the mineralogical and textural range of naturally occurring pelitic hornfelses is diverse. Spotted pelitic hornfels which develop in aureoles around large intrusive bodies, such as granite batholiths, will consequently have textures and mineralogies which reflect not only the conditions of contact metamorphism but also the original chemistry of the country rocks. Either cordierite or staurolite will be the main porphyroblastic (clot) mineral formed depending upon the aluminium and silica content of the original shale or siltstone. Iron, titanium and potassium in the original sediments will be concentrated in the resulting contact metamorphic minerals such as magnetite, rutile, spinel, muscovite and biotite. The range of potential pelitic hornfelses around the margins of a single intrusion is therefore highly variable, especially if post-contact metamorphic alteration processes, such as retrogressive metamorphism and metasomatism, have locally controlled the final mineralogy and texture,

As the *Sirius* anchored at Rio de Janeiro and Cape Town on her way to Botany Bay and as the officers may have had contact with those of ships which had visited India, the possibility of the artefact's being derived from these sources needs to be considered from a geological point of view.

It seems unlikely that the artefact was collected from the hinterland of Rio de Janeiro because the igneous and regional metamorphic rocks round there are of higher grade than the ***Sirius*** pelitic hornfels (Campos, Ponte and Miura, 1974). On the other hand contact metamorphism is associated with the Cape granites in the vicinity of Cape Town, South Africa. Dense hornfels, slates and argillaceous rocks have developed spotted appearances due to the formation of patches of cordierite (Truswell, 1970:97). it is possible, on geological grounds, for the ***Sirius*** artefact to be derived from a South African source even though the cordierite clots are often or entirely replaced by micaceous minerals. Samples of hornfels from the aureole of a Cape granite have not been examined petrologically. However, as pointed out earlier in this paper there is little anthropological evidence to support the proposition that the hatchet head is of South African origin.

In southern India, near the ports of Madras and Goa, the rocks are of the Dharwar Formation and predominantly comprise hornblende, chlorite and mica schists with lesser occurrences of mudstones, argillites, phyllites and schists containing kyanite, staurolite, cordierite and graphite (Pascoe, 1973). Favourable geological environments in which pelitic hornfels could form are found in the western parts of southern India. Gneissic, granulitic and charnockitic rocks, all of higher metamorphic grade to pelitic hornfels, and therefore containing different minerals and textures are developed on the eastern side of the continent.

Axe heads in southern India especially from near Bombay, are more likely to be manufactured from basaltic and doleritic dykes and flows and fine-grained regionally metamorphosed rocks, as these are such more common than the possible localised occurrences of pelitic hornfels. Samples of Indian hornfelses have not been examined but there seems to be reasonable evidence, from the general geology of southern India, to suggest that it is most unlikely that the ***Sirius*** artefact was collected from India. So, except for the remote possibility of the hatchet head being derived from outcrops near a Cape granite in South Africa the most probable source rocks are the gravels along the Nepean-Hawkesbury River.

Conclusion

Historical, formal and petrological studies all strongly suggest a source for the raw material for this artefact in the cobble beds of the Nepean River between Emu Plains and Richmond Hill. They also suggest that the hatchet head once formed part of the collection of 'curiosities' of an officer on board the ***Sirius***. It is an unexpected and intriguing find from an eighteenth century naval wreck. Yet it is also more than just a curiosity and an archaeological puzzle. The traditional patterns of technology and acquisition of raw materials for Aboriginal people of the Sydney Basin are represented. The hatchet head further symbolises the patterns of contact between Aborigines and the officers of the First Fleet, contact in which exchanges of artefacts, services and food were important to both parties.

List of Figures (not shown in this report)

Figure 1. The ground edge pebble artefact recovered in the ***Sirius*** excavation.
Photograph: Warren Hudson

Figure 2. Salvaging equipment and stores from the wrecked ***Sirius***, Norfolk Island, March 1790. This record by William Bradley, First Officer of the ship, shows the dispersal of items and the energy of wave action across the reef.

Figure 3. Illustration in *The Voyage of Governor Phillip to Botany Bay* 1789 (Plate opposite p.136) showing Aboriginal artefacts of the kind collected by officers of the First Fleet. The hatchet may well have been one of those given to Phillip by Aborigines met while exploring near Richmond Hill. It seems to be made on an unmodified pebble preform with features similar to those of the *Sirius* find. Reproduced by courtesy of the Mitchell Library, State Library of New South Wales.

Figure 4. The Nepean/Hawkesbury between Emu Plains and Richmond.

Figure 5 Cobble bed on the west bank of the Nepean below Richmond Hill - location 1 on Figure 4.
Photograph: Isabel McBryde.

Figure 6. Confluence of the Grose and Nepean with extensive areas of sand and gravels. Location 2. on Figure 4.
Photograph: Isabel McBryde.

Figure 7. Extensive cobble beds on the western bank of the Nepean at Emu Plains. Location 3 on Figure 4.
Photograph: Isabel McBryde.

Captions for Figures

Figure 1. The ground edge pebble artefact recovered in the excavation of the ***Sirius*** wreck.
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Figure 4. The Nepean/Hawkesbury between Emu Plains and Richmond. The hatchet areas indicate locations on which McCarthy recorded surface sites in his surveys.

	Locations 1, 2 and 3 are those on which cobble beds were sampled in field work for this paper. a - Lapstone Creek rock shelter b, c - Area of surface sites and grinding grooves recorded by McCarthy. d - Shaws Creek rock shelters investigated by Kohen, Stockton and Williams.
Figure 5.	Cobble bed on the west bank of the Nepean below Richmond Hill - Location 1 on Figure 4. Photograph: Isabel McBryde
Figure 6.	Confluence of the Grose and Nepean Rivers with extensive areas of sand and gravels. Location 2 on Figure 4. Photograph: Isabel McBryde
Figure 7.	Extensive cobble beds on the western bank of the Nepean at Emu Plains. Location 3 on Figure 4. Photograph: Isabel McBryde.

Appendix 2
Construction of a carronade carriage and an anchor stock

Geoff Kimpton
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Introduction

Prior to the 1988 ***Sirius*** expedition, it was decided that if time, labour and materials permitted, a stock similar to that fabricated in 1987 for the ***Sirius*** anchor at Kingston, Norfolk Island (Kimpton, 1987), should be made for the anchor raised by the ***Sirius*** Project in 1985. In addition, a carronade carriage should be made to take the carronade which was also raised in 1985. Even though the anchor and carronade were still undergoing conservation treatment on Norfolk Island, it was considered appropriate to prepare these accoutrements in advance for future display purposes.

Before leaving Perth the necessary plans were obtained and some of the steel fittings for the carronade carriage were fabricated.

The two construction projects were a joint undertaking between Norfolk Island personnel and members of the ***Sirius*** Project. The principle people involved were Franklin Randall from the Norfolk Island Restoration Team and Geoff Kimpton from the Western Australian Maritime Museum.

Carronade Carriage

The carronade was first manufactured by the Carron Iron Company of Falkirk, Scotland in 1778 and was shorter and lighter than ordinary guns (Lavery, 1987: 104 ff). Its shape was also different: it had only one reinforce and there was no swell of the muzzle. Early carronades were found to be too short, tending to set fire to the rigging. So, over time, the design underwent revision. The 18-pounder was one of the original carronades whose early design was characterised by the presence of trunnions.

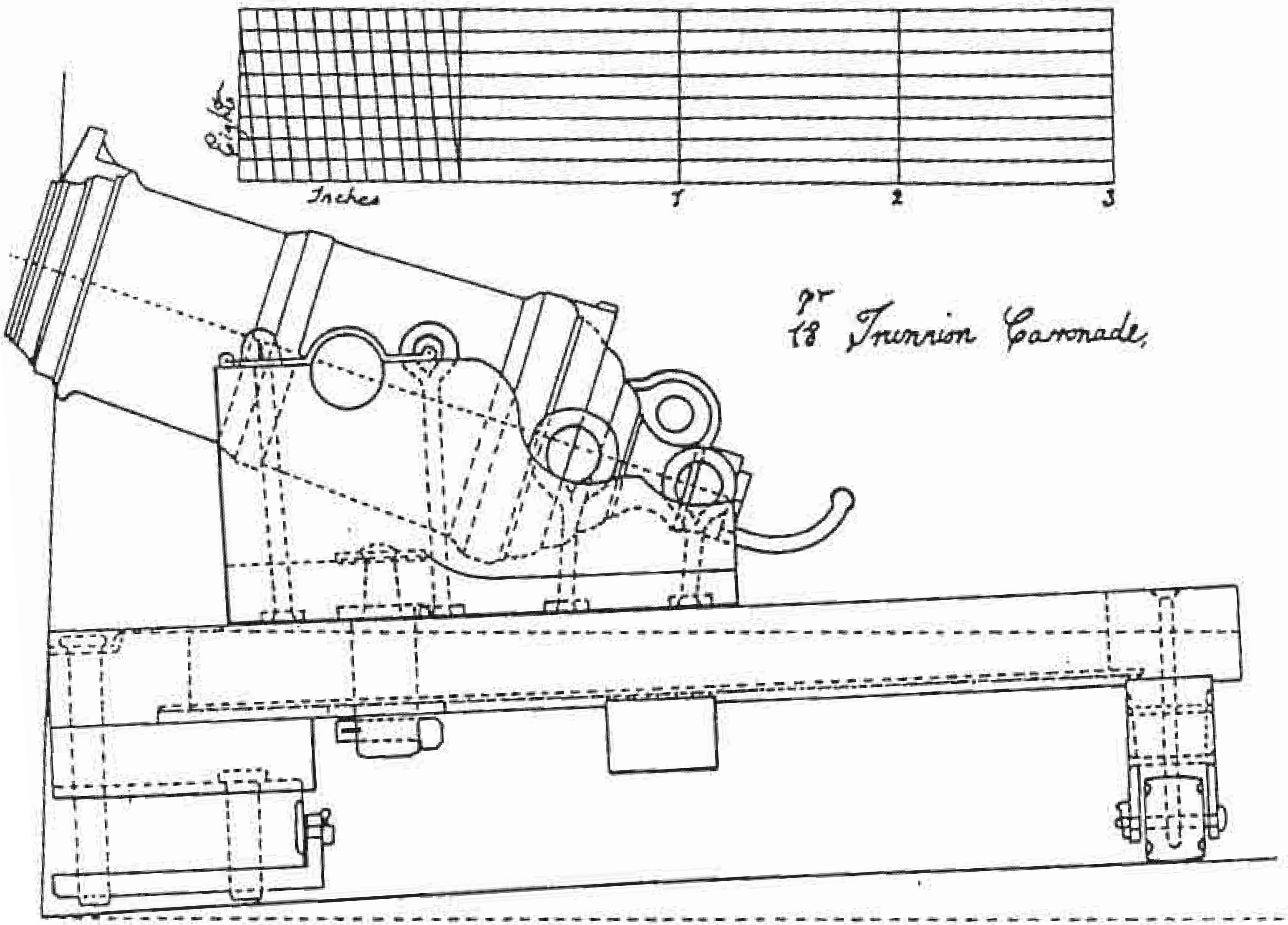
To get the best out of its guns, the Carron Company believed that special carriages were necessary (Lavery, 1987: 130). Indeed, the carriages used for carronades were radically different from those used for the rest of the Navy's guns (Lavery, 1984: 155). The carriage itself did not recoil with the gun, rather the gun was mounted on a slide which could move backwards over the bed of the carriage, thus allowing the recoil to be controlled; and the rear wheels of the carriage were arranged to allow the whole mounting to traverse, rather than recoil, making it much easier to swing the gun round in action. Carriages were usually made by the company and supplied with the gun as part of a package. Variations in the carronade carriage occurred over time in response to the changing design of the guns, their use on different types of ship and their positions on board. Essentially, however, 'it was a rational, scientific, development of the old truck carriage' (Lavery, 1984: 155).

Specifications

The only available plan which illustrates an 18-pounder trunnion carronade, (similar to that from the ***Sirius***), on its carriage, is a plan of c. 1800 held in the National Maritime Museum, London (NMM, Ships Plans Collection No. 7789). This early drawing gives a side elevation view only and is not very detailed (Figure. 1). The interesting aspect of the carriage is that it is a traversing type and probably represents one of the early forms of carronade mounting. Other plans used to obtain missing details were those of a 32-pounder carronade and 32-pounder with screw elevating gear, both by Bassett-Sowke Ltd, Northampton, England, and drawings from Brian Lavery's book *The Arming and Fitting of English Ships of War 1600 - 1815* (1987: 131).

According to Lavery (1987: 130), the standard type of carronade carriage, used on poops, forecastles and quarterdecks, had two main parts. The upper part, 'the bed', held the gun and enabled it to be elevated and depressed. This was then bolted to the

Figure 11 National Maritime Museum (London)
SHIPS PLANS COLLECTION No 7789 C1800



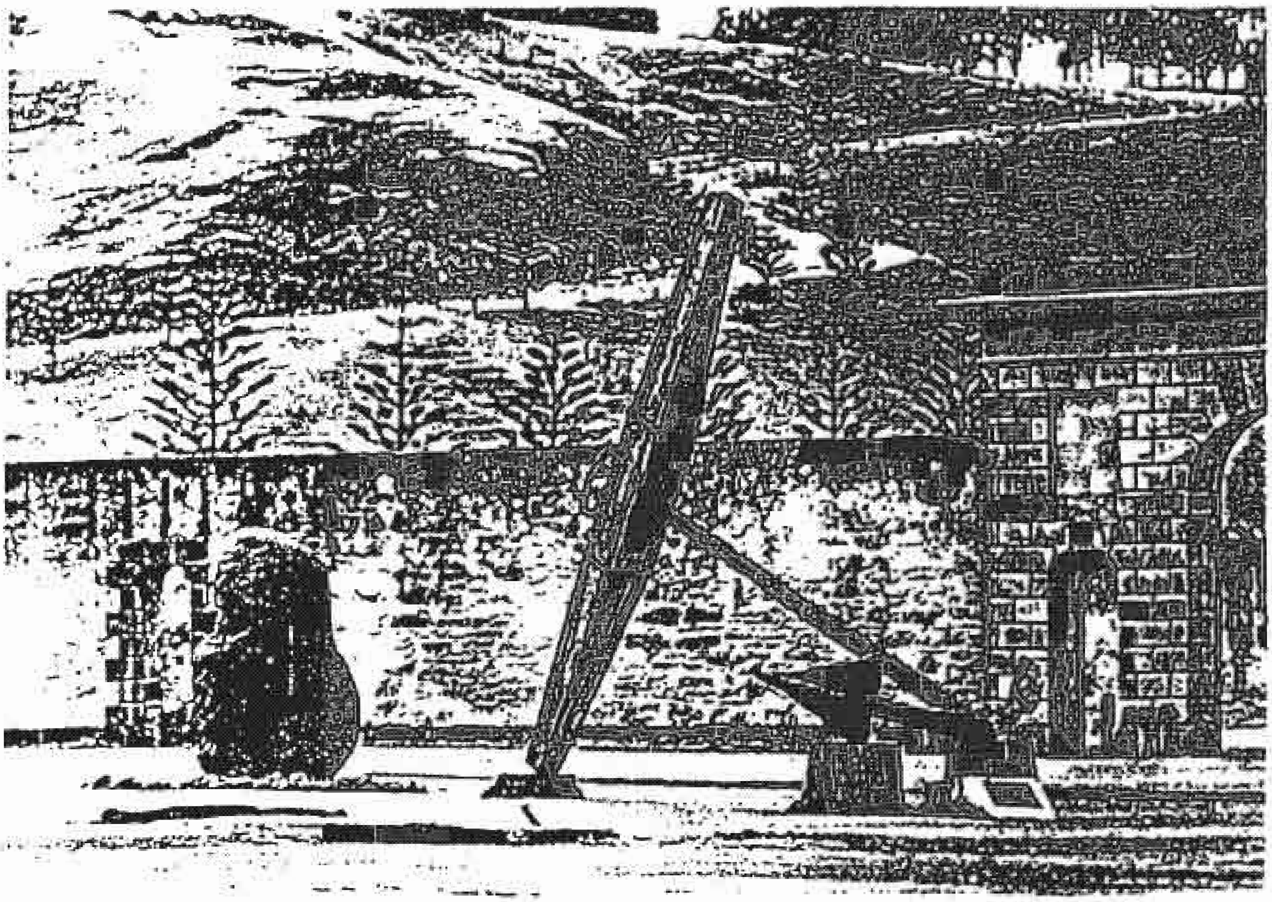


FIGURE 2 Sirius anchor NI20 displayed with the 1987 stock.

second part, 'the slide', or 'training bed', which allowed it to recoil. At its forward end, the slide rotated about a pivot so the gun could be traversed. The slide was a long piece of timber with a hole cut along its centre. Early carriages had rectangular slides but later, the fore edge was rounded off to allow better traversing (Lavery, 1987: 131). According to whether the gun was to be fitted on the 'outside' or 'inside principle', the foremost part of the slide was pivoted either inside or outside the hull (Lavery, 1987: 130; 132).

Lavery (1987:130) states that the 'outside principle' was 'probably the most common in the early days of the carronade, for it helped to carry the shorter gun outside the hull and rigging'. The disadvantage of the 'inside principle' up to the mid 1790s was that the 'carriages had only a very limited traverse, for the forward edge of the slide was usually cut square' (Lavery, 1987: 132). The rounding off of the end made movement easier and this seems to have been the norm after 1796. Guns mounted on the 'inside principle', however, were better protected from enemy fire (Lavery, 1987: 132).

The ***Sirius*** was ordered to be supplied with six 18-pounder carronades in 1786 and all of these were probably carried on the upper deck, possibly four on the quaterdeck and two on the forecastles (Henderson and Stanbury, 1988: 134). Whether they were mounted on the 'outside' or 'inside principle' however is not known. Two illustrations of carriages mounted on the 'outside principle' are shown in Lavery (1987: 131), one with a straight fore part to the slide and one with a rounded end. Both plans are dated to 1781 which indicates that both types of carriages were in use at this time. Presumably they could have been mounted according to either principle, unless the earlier rounded version was simply a design to improve the outward appearance of the carriage against the hull when mounted on the 'outside principle'. Lavery's suggestion that the square form was generally used up to the mid 1790s (Lavery, 1987:132) certainly creates a debatable issue and one which has arisen subsequent to the construction of the ***Sirius*** carronade carriage.

The carriage constructed for the ***Sirius*** carronade has been made with a rounded fore part to the slide which neither presumes that this would necessarily have been the the form used on the ***Sirius***, nor implies that it was mounted on the 'inside principle'.

Construction

Norfolk Pine, the local island timber, was used for the construction of the carriage as it was readily available in the large sizes required. Also, from previous experience we knew the timber to be good to work with and to give the required finished appearance.

Prior to commencement, the carronade measurements were re-checked when it was lifted from its conservation tank for inspection. Then the timber was shaped and fitted using tools and machinery belonging to the restoration team. Some outside labour for work such as docking and band sawing had to be used due to the large size of the timbers. The steel components were fabricated at the PWD, the staff being most helpful in assisting with the loan of equipment and the supply of materials. The finished steelwork was heated and dropped into sump oil to give it the desired appearance. After the carriage was assembled all the exposed timber was lightly burnt using oxy-acetylene and then rubbed over with hessian. This gave the desired finish.

The carriage was completed by 25 October when it was formerly presented to Mrs Gaye Evans, MLA, Secretary of the Norfolk Island Bicentennary Committee and Minister responsible for the Norfolk Island Bicentennial Musuem.

Anchor Stock

During the 1987 ***Sirius*** expedition Kimpton and Randall made a stock for the HMS ***Sirius*** anchor on display at Norfolk Island (NI 20) (Figure 2). A comprehensive compilation is given in the *1987 **Sirius** Expedition Report.* (Kimpton, 1987).

Having previously done the research as to the dimensions of the stock, it was simply a matter of adjusting them proportionally to fit the the anchor raised in 1985 (SI 57). This anchor is slightly shorter in length than the anchor raised in 1973, being 14 ft 11 in (4.55 m) compared to 15 ft 1 in (4.62 m) (Henderson and Stanbury, 1988: 132).

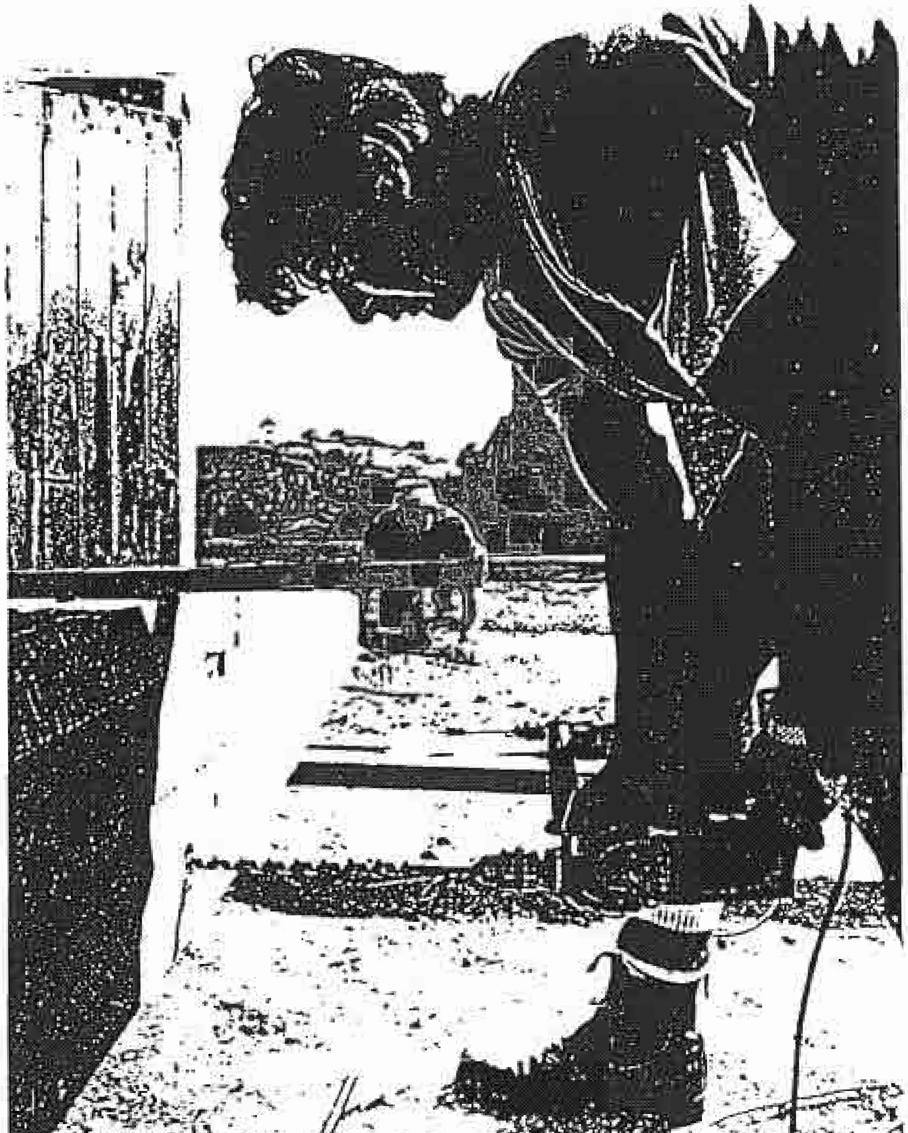


FIGURE 3 A stock is prepared for Sirius anchor SI57 in 1988.

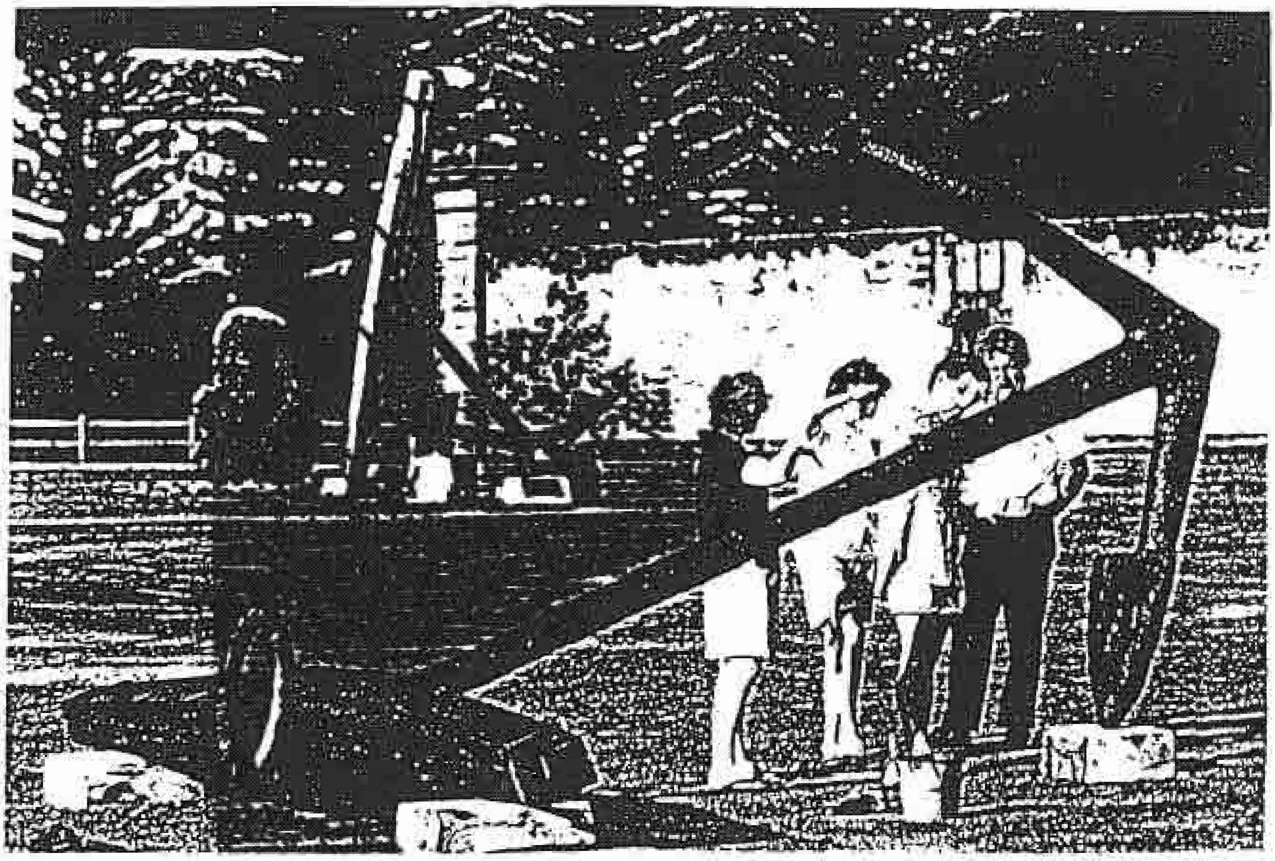


FIGURE 4 Sirius anchor SI57 with stock fitted,

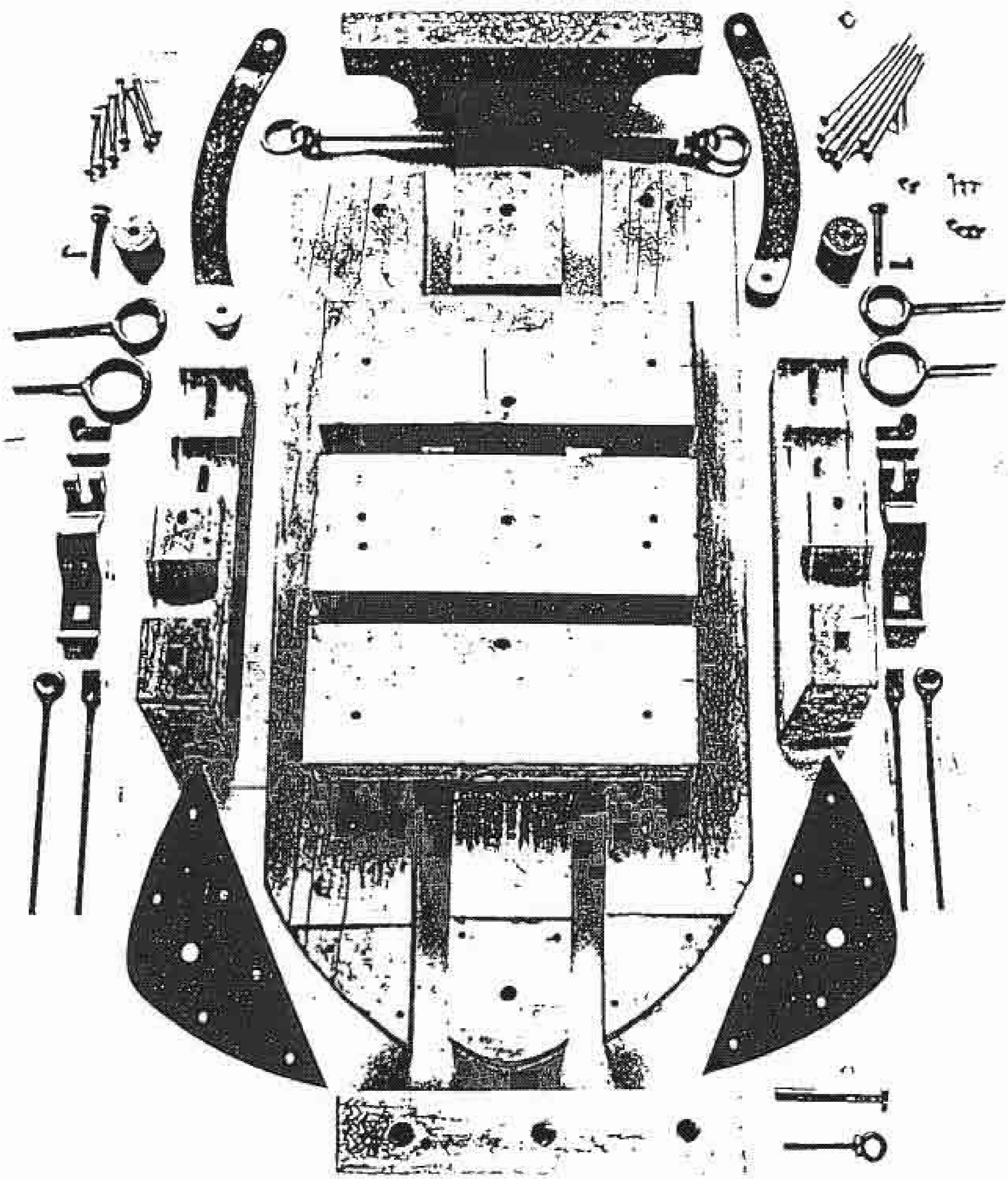


FIGURE 5 The parts for the carronade carriage.

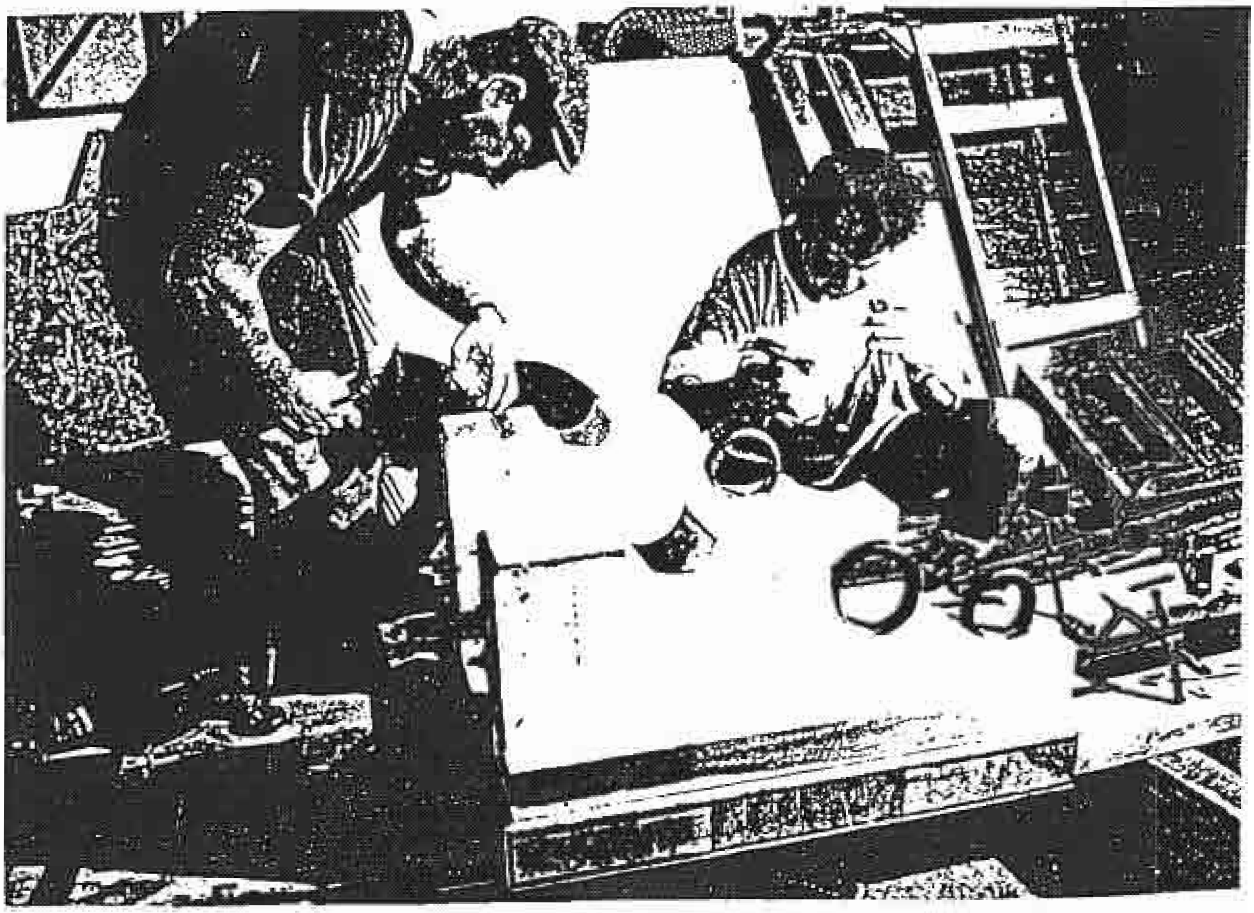


FIGURE 6 The carriage construction process.

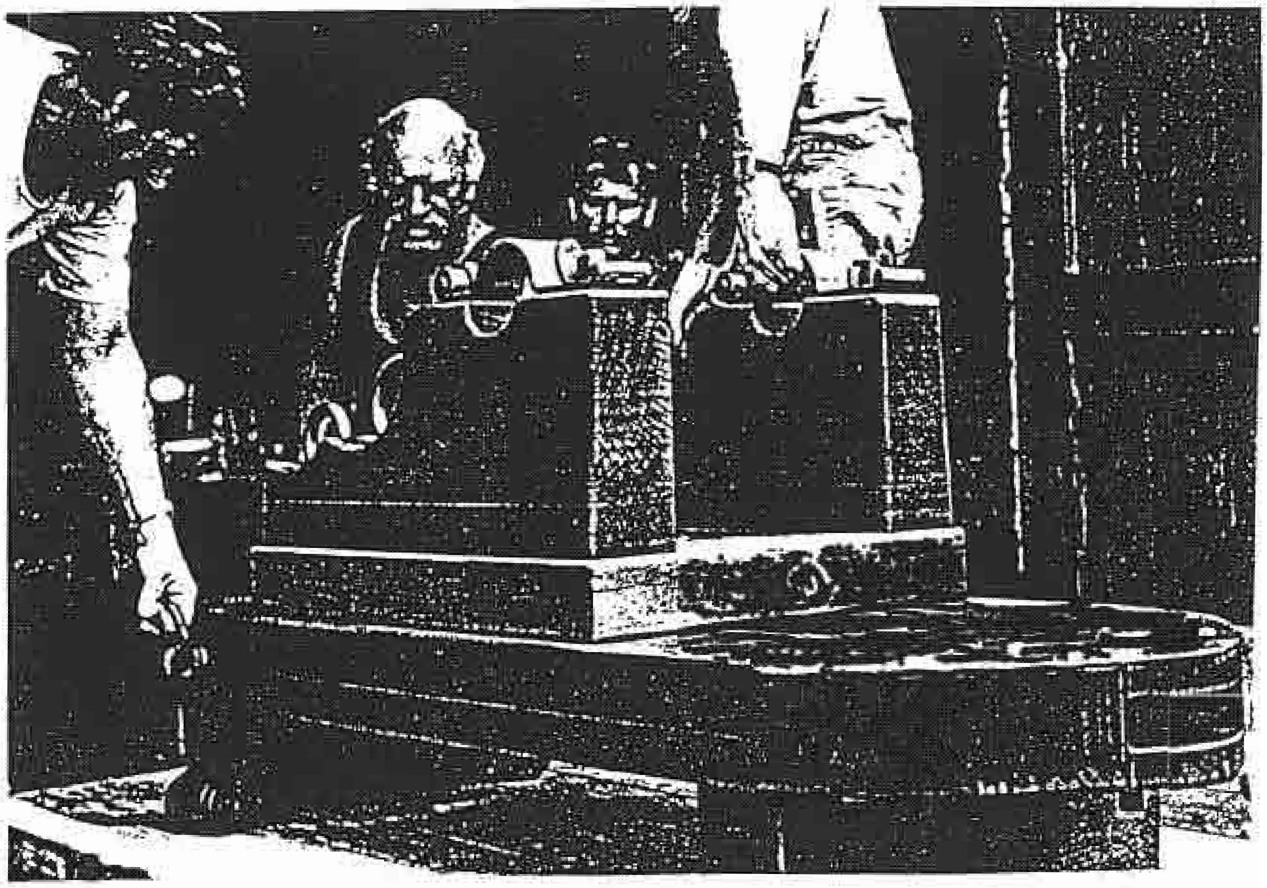


FIGURE 7 The completed carriage.

Norfolk Pine was used again and two lengths, milled to the specified dimensions, were obtained. The tapered lengths were cut using a chain saw.

In order to reduce the time spent on adzing it was decided to approach a visiting adzman, Cyril Dahl from Bundaberg, Queensland, present on Norfolk Island for the Royal Show. He agreed to do the adzing but found the timber to be a little too dry for optimum working: "green" or completely dry timber would have been easier to work and the timber provided was somewhere in between the two. The work, however, was completed in a day, whereas it had taken almost four before.

The steel bands and caps were made at the PWD and finished in the same way, by heating and dropping them into sump oil. The timber was also finished in similar fashion, by lightly burning and rubbing back.

In total, the anchor stock took seven days to complete. As the conservation treatment of the anchor was deemed to be complete, the final assembly took place at Kingston on Wednesday 19 October in time for the Duke of Norfolk's visit and the *Sirius* plaque unveiling. A decision was made for this anchor and stock to be loaned to the Australian National Maritime Museum in Sydney.

It was disassembled and flown out from Norfolk Island on 20 October. A wooden palette with protection for the anchor flukes was constructed in order to assist in air transportation and storage in Sydney until the anchor is placed on display. A complete list of all the component parts was prepared for the Australian National Maritime Museum and a diagram showing how they should be assembled. The anchor is considered to be one of the best preserved anchors from an historic shipwreck in Australian waters and should be a dramatic exhibition piece.

Appendix 3
Diving Schedule. Tom van Leeuwen.

Date Dive 1	Hrs	Dive 2	Hrs	Dive 3	Hrs	Dive 4	Hrs
03 Oct L T 0.9.30 am H.T.							
Jeffery	1.20	Henderson	0.20				
Kimpton	1.30	Arnott	0.20				
Baker	1.20	Edmiston	0.20				
Taylor	1.20	Tavener	0.20				
Tender:	**Tender:**						
Leeuwen	Baker						
04 Oct Bad Swell No Dives							
05 Oct Wind North-westerly, 2-15 knots. L. T. H.T.							
09.40						16.15	
Jeffery	1.00	Arnott	1.00	Mike	1.00	Henderson	1.00
Kimpton	1.00	Cresswell	1.00	Baker	1.00	Arnott	1.00
Baker	1.00	Barlee	1.00	Edmist	1.00	Jeffery	1.00
Leeuwen	1.00	Edmiston	1.00	Leeuwen	1.00		
Tender							
Edmiston		Henderson	0.45	Jeffery		Bevan	
06 Oct Wind North-westerly good conditions.weaker swell. L. T. H.T.							
09.35		c.11.20		14.20		16.15	
Mike J.	1.00	Barlee	1.00	George	1.00	Mike	1.00
Jeffery	1.00	Henderson	1.00	Jim	1.20	Arnott	1.00
Baker	1.00	Maree	1.00	Baker	1.00	Leeuwen	1.00
Leeuwen	1.00			Jeffery	1.20	Henderson	1.00
Myra	0.20						
Tender							
Maree		Leeuwen		Mike		Barlee	
Diving conditions excellent for last dive of the day.							
07 Oct. Wind NW 12/15 L.T.1135 H.T.1803 conditions poor strengthening swell							
08.35							
Leeuwen	0.50						
Mike	0.50						
Edmiston	0.50						
Baker	0.50						
Tender							
Henderson							
08 Oct Wind		L T 1230 H T 0623 strong swell					
No diving on site							
1320							
Johnson	1.00						
Cresswell	0.50						
Edmiston	0.50						
Baker	1.10						
Taylor	0.20						
Tender							
Taylor, Edmiston							
09 Oct Wind		L T 1317 H T 0722 strong swell					
No diving							

10 Oct Wind N-NW 10-15 L.T.1359 H T 0806 moderate swell

0840		1015		1630	
Henderson	1.00	Henderson	0.45	Leeuwen	1.00
Leeuwen	1.00	Edmiston	0.45	Jeffery	1.00
Arnott	1.00	Cresswell	0.45	Jack	1.00
Jeffery	1.00	Taylor	0.45	Taylor	1.00
Tender					
Johnson		Arnott		Cresswell	

0945-0950 Check on Current Meter
Henderson

---

11 Oct Wind ESE 15-18 L T 14 H T 0845 moderate seas & swell no diving

---

12 Oct Wind SSE 15-18 HT 0923 heavy seas & swell no diving on site , dived on current meter equipment located in 12-15 m of water & encountered strong groundswell at that depth.

13.30 hrs	
Leeuwen	1.00
George	1.00
Mike	1.00

Tender
Baker

---

13 Oct Wind E 7-10 HT 10 00 Swell moderating

---

14 Oct. HT 10.39 Wind SSW 5-6 knots. Low swell. Conditions good. Waves approximately 15 seconds apart.

08.10		10.20		11.30		13.30	
Graeme	1.10	Graeme	1.00	Pat	1.00	Maree	0.15
Bill	1.10	Pat	1.00	Grant Parker	1.00	Graeme	0.15
Terry	1.10	Ian	1.00	Bill	1.00	Tom	0.15
Marie	1.10	Tony Kennedy	1.00	Terry	1.00	Greg Mc	0.15
Tender							
Tom		Barlee		Barlee		George	

---

15 Oct. Wind SW 15-20 HT Heavy swell, waves approximately 9 seconds apart. No diving

---

16 Oct. Wind WSW 10 HT 12.12 Conditions excellent

1 9.00		2 10.30		3 12.00		4. 13.30	
Terry	1.15	Tom	1.00	Jim	1.00	Marie	0.15
Pat	1.15	Martin	1.00	Ian	1.00	George	0.15
Bill	1.15	B.Randall	1.00	Pat	1.15	Jack	0.15
Graeme	1.15	Marie	1.00	Graeme	1.15	Greg Mc	0.15
				Bill	1.15		
				Terry	1.15		
Tender							
Martin		George		Tom		Barlee	

TV crew from channel 9 dived 2.00 pm conditions poor
Chris , Bob , & Sonia , shown over site by Tom time 0.45

---

17 Oct Extremely Heavy Seas No Diving on Site

---

18 Oct -Heavy swell not possible to work site. Concrete pyramid with plaque towed to outer anchor ring by Admin work boat. Terry, Tom, & Pat swam with pyramid floated by 3 – 44 gal oil drums at H 13.30 hrs. Pyramid rested on flat rocky bottom
18 m ENE of anchor ring.

19 Oct HT 15.09 Wind SE 5_7 Knots Swell Moderate.
Dive 1 7.40 am Dive aborted.

Graeme	.15
Bill	.15
Marie	.15
Tom	.15
Tender	
Barley	

---

20 Oct Extremely heavy swells no diving on site. Geoff & Franklin completed stock for 85 anchor. Anchor loaded and sent to Sydney on RAAF Hercules.

---

21 Oct Weather stormy, wind gusting to 40 knots due South. No diving on site.

---

22 Oct Extremely heavy swells no diving on site.

---

23 Oct Light winds moderating swell , conditions good.

Dive 1 - 8.00		2 - 10.00		3 - 12.00		4 - 15.00	
Terry	1.50	Tom	1.50	Graeme	1.5	Graeme	1.50
Graeme	1.50	Ian	1.50	Terry	1.50	Bill	1.50
Geoff	1.50	Graeme	1.50	Martin	1.50	Terry	1.50
Bill	1.50	Pat	1.50	Bill	1.00	Geoff	1.00
		Marie	0.15	Tom	1.00	Tom	1.00
Tender							
Marie		Martin		Paul		Marie	

---

24 Oct HT 07.20 light NW winds low swell conditions good. Several cannon balls raised together with ballast pig from main mound.
Worked with two divers in the excavation area at one time.

Dive 1 - 7.30		2 - 9.00		3 - 10.30		4 - 11.00	
Graeme	1.00	Tom	1.00	Jim	.25	Graeme	1.00
Bill	1.00	Pat	1.00	Myra	.25	Jim	1.00
Marie	1.00	Ian	1.00	Martin	.50	Mike	1.00
Basil Randal	1.00	Barlee	1.00	George	.50		
		Terry					
Tender							
Martin		Martin		Tom		Barlee	

Dive 5 - 16.00		6 - 17.00	
Marie	1.00	George	1.00
Barlee	1.00	Mike	1.00
Bill	1.00	Pat	1.00
		Tom	1.00
Tender			
Martin		Terry	

25 Oct HT 8.12 Wind Light SSE Swell low to moderate , good site conditions.

Dive 1 _ 7.30		2 - 9.00		3 - 10.30	
Terry	1.25	Martin	1.25	Bill	1.00
Barlee	1.25	Tom	1.25	Marie	1.00
		Pat	1.25	Mike	1.00
Tender					
Mike		Mike		Barlee	

26 Oct HT 9.45 Light SSE winds swell low to moderate good site conditions.

Dive 1 7.45		2.-.9.00		3.- 10.30	
Terry	1.00	Bill	1.00	Mike	1.00
Barlee	1.00	Mike	1.00	Graeme	1.00
		Graeme	1.00		
		Pat	1.00		
Tender					
Tom		Terry		Barlee	

27 Oct Wind SSE low swell perfect site conditions.

Dive 1 - 8.00		2 - 9.30		3 - 11.00		4.- 14.30	
Tom	1.00	Bill	1.00	Tom	1.00	Current meter	
Mike	1.00	Marie	1.00	Martin	1.00	George	.50
		Graeme	1.00			Marie	.50
						Mike	.50
Tender.							
Terry		Barlee		Mike		Tom	

28 0ct HT 10.31 Wind ESE Low swell good site conditions.

Dive I - 8.00		2 - 10.00		3 - 11.30		4 - 13.00	
Barlee	1.00	Bill	1.00	Martin	1.00	George	1.00
Terry	1.00	Marie	1.00	Tom	1.00	Jim	1.00
Graeme	1.00	George	1.00	Marie	1.00		
Mike	1.00	Pat	1.00	Bill	1.00		
Tender							
Tom		Barlee		Barlee		Mike	

29 Oct HT 11.19 Wind due N low swell perfect site conditions.

Dive 1 - 8.30		2 - 10.30		3 - 13.30	
Terry	1.25	Tom	1.25	Tom	1.00
Barlee	1.25	Mike	1.25	Martin	1.25
		George	1.00	Pat	1.25
		Martin	1.00	George	1.25
				Graeme	1.00
Tender					
George		Marie		Jim	

Appendix 4
Reports and Publications arising directly or indirectly from the Project

A. Publications

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