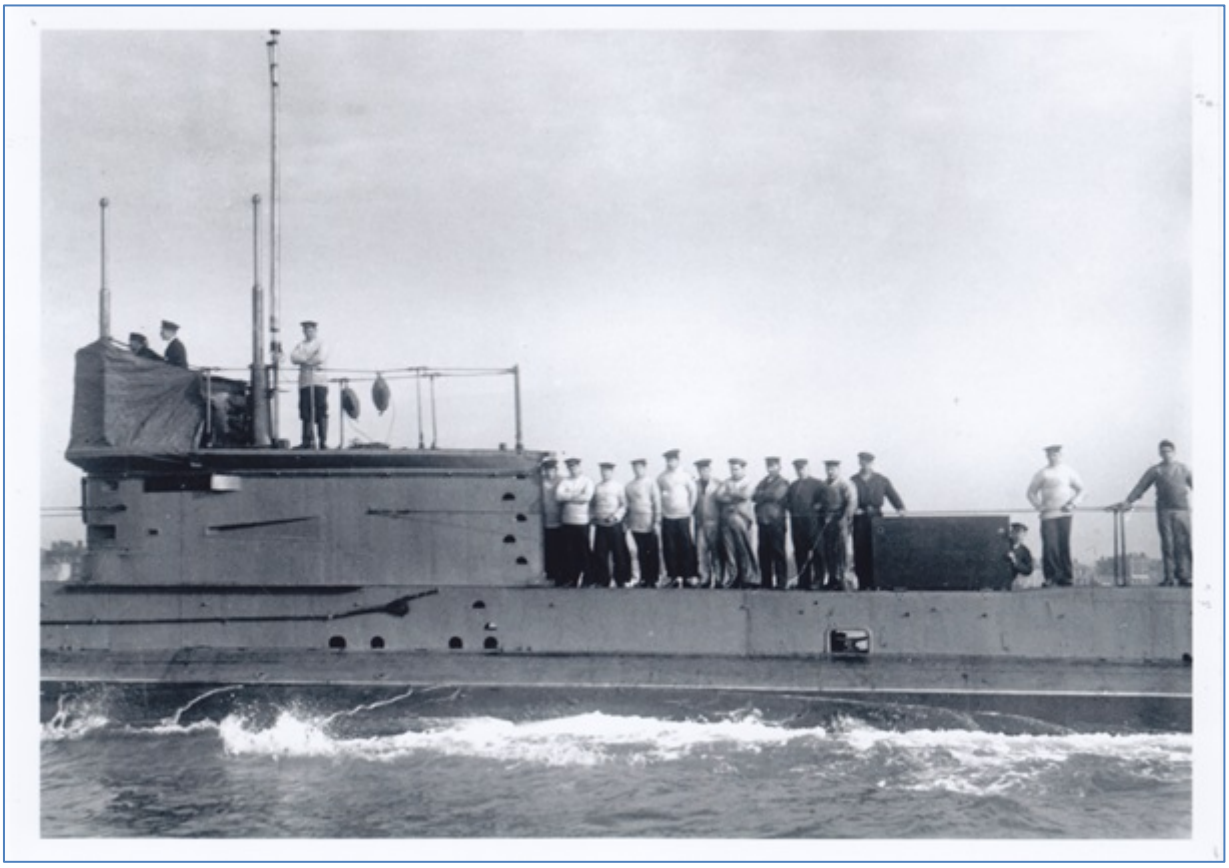
# HMAS *AE1*

## Main Report – Finding the Men of *AE1* – 20 December 2017

Version 2
November 2018

Find The Men of AE1

**HMAS *AE1* Arrives at Portsmouth - 17 February, 1914 (Image: Darren Brown)**



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# Executive Summary

The men of *AE1* have been found. The successful outcome relied on a combination of the research and analysis that went into drawing up the search areas combined with the skill and technology deployed by the crew of MV *Fugro Equator*.

The search would not have been possible without the funding and backing provided by the Australian Government, Royal Australian Navy (RAN), the Australian National Maritime Museum (ANMM), their funding arm, the Australian National Maritime Foundation (ANMF), The Silentworld foundation and their sponsors (listed at Annex A) and Fugro. The Chairman of the ANMF and founder of the Silentworld Foundation, Mr John Mullen, provided a personal guarantee for the ANMF's fundraising that enabled the search to proceed at short notice.

The Submarine Institute of Australia (SIA) provided funding and support throughout the 6-year project to find the men of *AE1*, in doing so they provided the financial foundation for the Project. Equally notable, the Find *AE1* Ltd (Find *AE1*) Board, a group of volunteers, have wisely directed the efforts of the team of Find *AE1* volunteers.

Following a workshop at the ANMM in 2016, the Defence Science and Technology Group (DST Group) verified the search area with analysis based on the most likely scenario, a practice dive *en route* to Rabaul. Marine survey company iXblue acted *pro bono* as the prime contractor to prepare a costed plan for a 30-day search using towed sensors. This was used as the basis for obtaining Federal Government funding.

Find *AE1*'s efforts to reach out to the offshore industry bore fruit in September 2017, when survey company Fugro advised that they had a suitably equipped ship operating in Papua New Guinea (PNG) waters. A fixed price contract to comprehensively search the area set out by Find *AE1* ensued. Fugro provided favourable terms, including carrying the risk of any extension due to miscalculation of the task, weather delays or equipment defects. This was substantially cheaper and offered the superior technology of the Autonomous Underwater Vehicle (AUV), deployed from a specialised search vessel, by a highly experienced survey crew.

After an intense period of activity that included negotiating funding agreements and obtaining the necessary approvals, an eight-person Expedition Team drawn from the Silentworld Foundation, RAN, ANMM and Find *AE1* and a 14-person Fugro survey crew sailed from Port Moresby aboard the *Fugro Equator* on 13 December.

The ship entered the search area *en route* to port clearance in Rabaul on 18 December 2017. It then sailed to the northern end of the search area, whilst collecting bathymetric data using its powerful EM 302 Multi Beam Echo Sounder (MBES). After completing sound/velocity profile measurement of the water column to the seabed, the first AUV mission was launched that evening. Examination of the data gathered after recovery of the AUV on the following evening, 19 December revealed that it's Side Scan Sonar (SSS) and MBES had detected a contact with similar dimensions to *AE1*. Further analysis located the same contact, detected during the ship's initial MBES survey.

The AUV was diverted from its next programmed search to examine the contact more closely. The results added sufficient confidence to suspend the search on the morning of 20 December and examine the contact using a drop camera. The Drop Camera is a metal frame fitted with lighting, a colour, real time video camera and a colour stills camera, triggered on demand, suspended beneath the ship.

As the contact came into view on the Drop Camera's video feed from the seabed over 300m below, it was apparent that *AE1* and its crew had been found.

The wreck site was examined for several hours using the Drop Camera. This was followed up by an AUV survey using its fitted black and white still camera to obtain over 6,000 shots. These were skilfully merged by Fugro to provide a mosaic overview of the wreck.

Analysis of the cause(s) of the loss must be qualified at this stage as it is a complex shipwreck. Resolving what led to the loss is made more difficult by the damage incurred to the submarine's hull

during the sinking process, possible post sinking events and corrosion due to the march of time. The images are all from an overhead (plan view) perspective, however consensus has been reached in the team undertaking the analysis, their conclusions have been verified by the DST Group[1] and Mr John Jeremy AM.[2]

The most likely cause of *AE1*'s loss appears to be a diving accident:

- *AE1* was probably already submerged or in the process of diving when the accident occurred.
- The wreck's position is consistent with a course to return to Rabaul.
- It appears that the submarine experienced a depth excursion and exceeded its crush depth, leading to the implosion of the hull forward of the fin in the control room area and over the forward torpedo compartment.
- The flooded submarine sank rapidly to the bottom and probably landing on its keel, with a moderate bow down angle since the bow torpedo tube is relatively intact.
- What follows is plausible speculation:
  - We believe it then pitched forward, to strike the seabed with its bow.
  - It is possible that the implosion had already begun the process of dislodging the fin; we believe the resultant whiplash effect, caused or completed dislodgement of the fin and caused it to tilt forward onto the partially collapsed forward casing.

The team has determined that there is a low probability of obtaining further clues about *AE1*'s loss from entering the surviving hull, and consequently advises against an internal examination. This view is reinforced by the fact that the submarine is the final resting place of its 35 crewmen and deserves the sanctity due to a grave site.

However, the team also believes that a follow-up archaeological survey of the site that employs high-definition still and video cameras, a large lighting array and an underwater laser scanner should be conducted to comprehensively document *AE1*'s exterior hull. Such a survey would provide a 3D model of the wreck site that could contribute to an understanding of its loss, assist in determining a strategy for its long-term management and provide interpretive material for the ANMM to tell its story to a wide audience. It would also reduce the attraction for an illicit examination.

The need to protect *AE1* from unwarranted intrusion and exploitation is now a priority. Individuals and organisations, including well-resourced amateur "marine archaeologists", have indicated an interest in locating the site and exploiting it for their own personal gain. As a consequence:

- Joint Australian and PNG action will be necessary to establish an exclusion zone around *AE1* and preclude any unsanctioned activity on or near the wreck site.
- Inhabitants of the nearby Mioko Islands have a clear view of the wreck site's location and are probably the cheapest and most effective means by which PNG and Australian authorities may be alerted to unauthorised visits to the site.
- A framework should be established by which the Australian government could provide Mioko Islanders with annual gifts, such as educational material and sporting gear in return for their assistance in monitoring the site.

*AE1* and its crew have been found – we must now move urgently to protect their grave from unwanted intrusion or exploitation.

[1] The Chief Defence Scientist, Dr Alex Zelinsky AO provided support throughout the project, authorizing the participation of the Chief of the Maritime Division of the Defence Science and Technology Group, Dr David Kershaw, Naval Architect Dr Stuart Cannon and Dr Roger Neill, who have all given freely of their time to critically review the findings.
[2] Mr John Jeremy AM BE FIEAust FRINA, is a naval architect, the last Chief Executive Officer of Cockatoo Island Dockyard and is experienced in working on submarines. He is a past President of the Royal Institution of Naval Architects, Australian Division.

# 1 Introduction

## 1.1 Acknowledgements

Thanks are due to the:

- Commonwealth Government;
- Royal Australian Navy;
- Silentworld Foundation;
- Australian National Maritime Museum, its Foundation and their sponsors listed in Annex A;
- Submarine Institute of Australia;
- Defence Science and Technology Group;
- RAN Hydrographer and RAN Historical Section;
- Fugro*;* and
- Numerous volunteers who have given their time and expertise to make this possible. See Annex A List of Sponsors and Volunteers.

The Find *AE1* Board provided wise counsel and oversight during the six years of the Project to find the men of *AE1*.

Finally, we wish to state our particular thanks to John Mullen; without his personal commitment and support, this search and its successful outcome would not have happened.

## 1.2 Previous Searches

Acknowledgement for the efforts of those who have searched for the men of *AE1* prior to this expedition are due. In particular, the efforts of Commander John Foster OAM, RAN Retired who devoted many years of his life to locating the submarine and its crew are acknowledged.

Dr Michael White OAM QC and the team at *AE1* Incorporated (*AE1* Inc) took over this legacy and maintained the effort to find *AE1*. They also initiated commemorative events, including the installation of plaques by Dr Ross Bastiaan AM RFD at Garden Island, Sydney and Bita Paka Commonwealth War Cemetery at Kokopo, PNG.

Details of the preceding searches are in Attachment 1.

## 1.3 Background to December 2017 Search

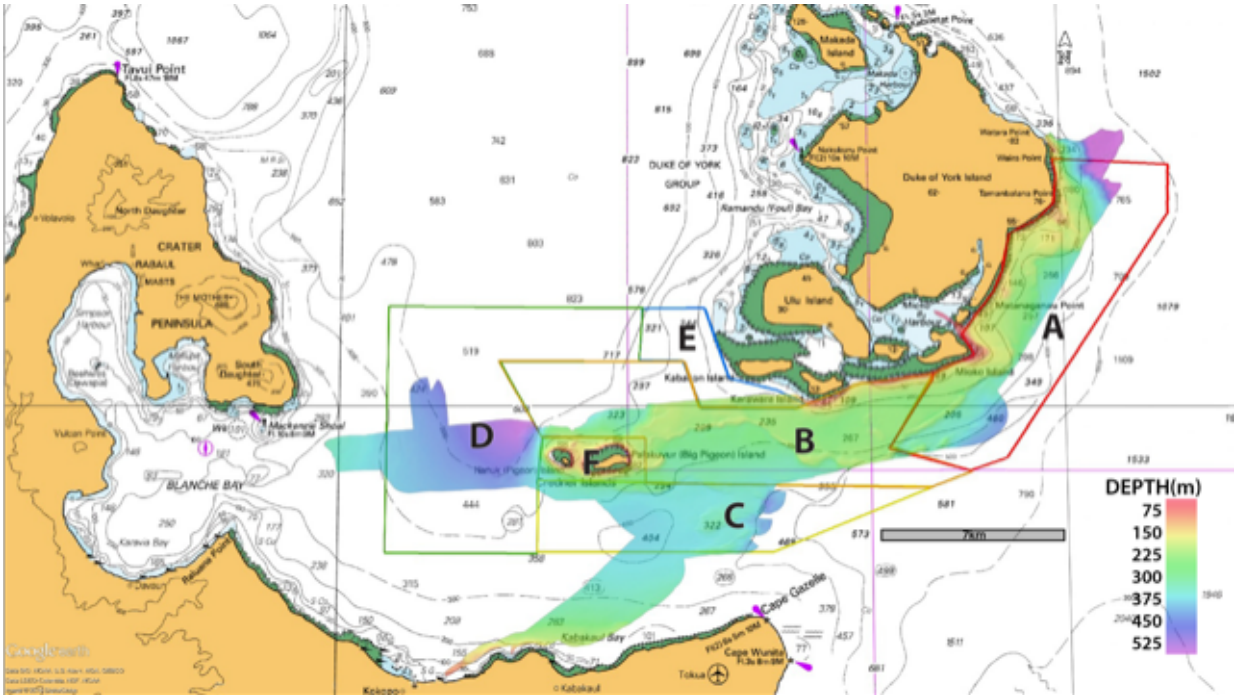
*AE1* Inc published the combined efforts of the research team in February 2012,[3] in a document referred to as the *"Search Report"*. This group formed the core of the Find *AE1* planning team, formed in December 2013 to obtain funding and manage the search. This research was the genesis for the successful search in 2017.

The seed for the involvement of Fugro[4] was planted in January 2015, when Find *AE1* issued a letter seeking Registration of Interest from industry (Attachment 2 refers). This was followed up on 21 June 2016, when a talk by Find *AE1* on the *AE1* Project was given to the World Hydrography Day in Canberra. However, there were many critical steps between that event and the offer from Fugro in September 2017.

As a result of a workshop to review Find *AE1*'s research held at the Australian National Maritime Museum (ANMM) on 5 December 2016, the conclusions of the *Search Report* were varied and an agreement was reached on the search area and methodology (Attachment 3 refers).

[3] SUBSUNK HMAS *AE1* 14 September 1914, dated 1Feb12, http://findae1.org.au/reports/ae1-search-report-2012/
[4] Fugro NV is a Dutch Company operating in Australia which is a global leader in offshore survey, offshore geotechnical and seabed geophysical services. They participated in the initial search for MH370.

**Figure 1 - Search Areas (Credit: iXblue)**




Most significantly, at a meeting facilitated by the Director of the ANMM, Kevin Sumption, following the workshop, John Mullen, Founder and Director of the Silentworld Foundation (SWF) and Chairman of the Australian National Maritime Foundation (ANMF), the ANMM's support organisation, indicated in-principle support to fund a search.

The search area was refined using a probabilistic analysis by Dr Neil Gordon's group at the Defence Science and Technology Group's modelling team in Edinburgh SA in late December 2016.

The workshop and analysis were used to develop a project plan and obtain budgetary costings from offshore industry service providers by Mr David Donohue CEO of iXblue Australia[5], who had responded to the Registration of Interest letter and acted *pro bono* as the prime contractor assembling quotations from the various sub-contractors to supply equipment and services, facilitated this process. This resulted in a budgetary figure of $2.4M for a 30-day towed Side Scan Sonar (SSS), Sub Bottom Profiler (SBP) and magnetometer search.

# 2 Preparations for the 2017 Search

## 2.1 Funding Arrangements

Following in-principle agreement from Australia's Department of Defence to fund 50% of these costs, on the understanding the SWF had also committed to fund an equal share, a funding proposal was submitted to the Australian Federal Government. The target date for the search was November 2018. Ministerial approval to fund up to $1.2M under this model was obtained on 28 September 2017.

Fortuitously, a follow up request from Fugro for further information, resulted in a meeting with Mr Paul Seaton, Fugro's Regional Business Development Manager for Asia, at the ANMM on 19 September 2017. By early October 2017 this matured into an offer for the *AE1* search team to utilise *Fugro Equator* once prior scheduled survey work in PNG was completed. The planned start date for the survey was late November 2017 and was estimated to cost $1.75M.

The significantly shorter timescale did not allow sufficient time for SWF to fundraise for the initial cost estimate and a reduced, fixed price of $1M was negotiated with Fugro. This cost involved some risk to Fugro; if the search utilised all of the allocated time, Fugro would be subsidising the activity. The costs

[5] iXblue is a French Company which is a leading global provider of innovative solutions and services for navigation, positioning, and imaging; in Australia they are Marine Survey Specialists.

for travel for three Find *AE1* personnel and one photographer/videographer as well as documentary production costs added a further $40K. This cost was met by a generous $20K grant from the ANMM and an equal share from the SIA.

Australia's Minister for Defence, The Hon. Marise Payne, publicly announced government support for the *AE1* search in an interview with a journalist on 7 November 2017. The story ran on 11 November following a national media release issued by the Department of Defence.

A period of intense activity followed to obtain the necessary visas, approvals and negotiate three Funding Deeds.

The Funding Deed between the RAN and Find *AE1* was concluded on 6 November (Attachment 4 refers) and $550k (i.e. the $500k plus GST) was deposited in Find *AE1*'s bank account.

After discussions with SWF, the decision was made for the ANMM's funding arm, the Australian National Maritime Foundation (ANMF), to provide the other 50% of project costs via donations received from sponsors listed at Annex A to a fund set up for this purpose.

The ANMF commitment was backed by a personal guarantee from Mr John Mullen to meet any shortfall. The supporting Deed between Mr Mullen and Find *AE1* was concluded on 20 November. This generous commitment provided a foundation to build on and critical assurance to the Find *AE1* and ANMF Boards to facilitate conclusion of a Funding Deed between the ANMF and Find *AE1* on 23 November (Attachment 5 refers).

Payment of the Fugro contract was provided in two tranches; $200k to cover the initial payment was deposited on 30 November 2017. The SIA provided an interest free loan to cover the cost of GST, which was to be paid by Find *AE1* on the ANMF's share.

With the predicted mobilisation date of 12 December 2017, only 18 days away, the focus turned to executing the previously agreed draft contract with Fugro and preparing for the deployment.

These preparations were completed by 11 December and the Principals updated with a final Brief (Attachment 7 refers).

## 2.2 The Contract with Fugro

The contract with Fugro comprised a fixed price of $1M; the agreed task was to undertake a comprehensive AUV search of the area set out following the DST Group's analysis.

- Twelve days were planned to complete the survey, but Fugro assumed the risk for extensions due to weather, problems associated with equipment or miscalculation of the task.
- The fee was to be paid in two instalments, $200k on signature of the contract and $800k within 30 days of Fugro's invoice, which was to be submitted upon completion of the search.
- Extensions requested by Find *AE1* to the 12 day search would be charged at the company's fully daily operational rate.
- As the primary objective was to locate and identify *AE1*, a further cost free extension of up to 8 hours was agreed for drop camera examination of the wreck site in the event it was found.

A copy of the contract and further details of issues arising from it are attached to the Decision Brief for Principals dated 24 November (Attachment 6). This document and its attachment contain sensitive commercial information and are not for public release. A hard copy of this attachment is included in the ANMM's original copy of the report.

The contract between Fugro and Find *AE1* was signed on 30 November 2017 and a payment of $220k was subsequently made to Fugro.

## 2.3 Approvals

All Expedition Team members entered PNG on multiple-entry business visas. Application for visas took approximately two weeks and was facilitated by a letter of support from Chief of Navy (RAN) to the PNG Acting High Commissioner in Canberra. Team members carried a letter explaining their role and the purpose of the project (Attachment 8 refers); in the event these were not called for.

Efforts to obtain a Letter of Support from the PNG Chief Secretary to Government, as had been obtained prior to Find *AE1*'s November 2015 MBES survey, were overtaken by a fortuitous opportunity. Find *AE1* was able to request the Prime Minister (PM) of PNG's approval, utilising an intermediary with access to the PM. Verbal approval from the PM quickly followed.

A Research Proposal was submitted to the PNG National Museum and Art Gallery (NMAG) on 31 October 2017 (Attachment 9 refers).

- The NMAG has legislative oversight of World War II relics.
- If this legislative oversight could be extended to include World War I relics this could provide a useful option for ongoing protection of *AE1*.
- An NMAG permit approving a non-invasive survey of the *AE1* wreck, (if found) was issued on 11 November (Attachment 10 refers).
- This was used by Fugro as the "letter of invitation" required under the visa rules to obtain work visas for the Marine and Survey crews of *Fugro Equator*.
- Efforts to embark an NMAG observer for the search were unsuccessful; the short timescales precluded completion of suitable arrangements.

Fugro briefed the PNG National Maritime Safety Authority on the deployment[6]. The vessel was required to "clear in and out" with Port Authorities in Rabaul.

## 2.4 Project Management

Find *AE1* acted as the project manager and provided two *Briefs to Principals* (RAN, ANMM and SWF), (Attachments 6 and 7 refer).

- The first Brief was used to obtain a decision from the Principals to proceed to contract.
- The second updated them on arrangements for the search.
- A parallel pattern was followed in briefing the Find *AE1* Board; their agreement was obtained as a pre-requisite, prior to approaching the Principals.

Each member of the Expedition Team signed an individual Agreement, which specified the basis for participation (Attachment 11 refers).

## 2.5 Ownership of Images & Data

All images in this Report are credited to Find *AE1* unless otherwise annotated. These rights are to be transferred to the ANMM on completion of the project.

# 3 The Search – Daily Log

## 3.1 Arrival & Accommodation in Port Moresby

The Expedition Team of eight (Annex B) arrived together on a Qantas flight (QF 349) from Brisbane at 1350 on Tuesday, 12 December 2017. Customs and immigration formalities were uneventful and the group was transferred to the Holiday Inn Express by a private security contractor, Guard Dog Security.

Arrangements to take two of PNG National Museum and Art Gallery (NMAG) personnel to visit the ship unravelled when they arrived and advised that they had a prior engagement that afternoon. The NMAG party comprised:

[6] http://nmsa.gov.pg

- Dr Andrew Connelly, Military Heritage Adviser;
- Mr Senea Greah, Senior Curator Modern History; and
- Mr Nick Araho, Archaeologist and Project Consultant.

They were briefed on the project over an informal lunch and gave assurances that a permit to a third party to examine the wreck would not be issued without the agreement of Find *AE1*. This assurance was confirmed by a subsequent email exchange.

## 3.2 Joining *Fugro Equator* – Wednesday 13 December 2017

The transfer to the ship at the secure AES port area was completed without incident by Guard Dog Security. The Expedition Team joined the ship at 1330, in the midst of a hectic changeover period for the incoming crew, who were busy completing pre-sailing preparations.

**Figure 2 - MV *Fugro Equator***


After the team settled into the allotted single berth cabins, the Expedition Team underwent a comprehensive safety induction briefing that was delivered by the Chief Officer at 1500. This was followed by a quick tour of the ship. The incoming Master was new to the ship and was backed up by his outgoing counterpart, who departed the following day after the ship transited to the refuelling jetty. All the deck and engineering officers were Russian speakers.

A total of 37 persons were aboard; 14 in the *Fugro Equator* Survey Crew, 15 in the ship's Marine Crew and 8 in the Expedition Team. The Survey Crew were a separate group and not part of the ship's Marine Crew. The Marine Crew consisted of Lithuanian, Russian and Ukrainian officers, supported by Filipino deck and catering crew. The Survey Crew were Malaysian and Indonesian nationals and the principal geophysicist was a British national based in Perth. The team worked effectively and efficiently, having extensive experience in working together on prior projects.

Fugro NV has very well developed and closely documented procedures for operations and emergencies, which facilitates a rapid turnover and easing of integration for new crew members.

A "kicking off meeting" was held at 1600; all members of the Survey Crew, Expedition Team and the incoming ship's Master were present.

## 3.3 Departure from Port Moresby – Thursday, 14 December 2017

The ship sailed at 0850 after embarking the pilot and conducted a short transit to the Napa Napa fuel jetty. Fuelling was completed by 1355 and the ship waited until 1720 for a pilot, before sailing at 1738. During the afternoon, the Expedition Team members received training in processing the side scan sonar images obtained from the Autonomous Underwater Vehicle (AUV) and a procedure was established to enable any contacts detected by them to be recorded for follow up analysis.

At 1830, having dropped the pilot earlier, the ship cleared the Basilisk Channel and turned east-south-east to begin the 770 nautical mile (1426 Km) transit via Jomard Passage to Rabaul. The ship proceeded at an economical transit speed, of 70% power, resulting in a speed made good of 8-9 knots – a slow passage!

The transit continued on Friday, Saturday and Sunday. The opportunity was taken to brief the Survey Crew on the characteristics of *AE1* and its story. The Survey Crew briefed the Expedition Team on the ship's two fitted Multibeam Echo Sounder (MBES) systems and the interpretation of collected data. A presentation on the AUV handling and characteristics was provided for the Expedition Team. The incoming ship's Master, who was unfamiliar with the equipment, also attended.

An emergency evacuation, fire and abandon ship drill was conducted on Friday.

Overnight on Sunday as Cape Gazelle was approached the weather deteriorated, with sharp, heavy showers and squalls from the northwest. A contrary current slowed progress and power was increased to 80% to make better headway. Plans to commence an MBES sweep to the northeast along the outer edge of the search area were abandoned in order to be in Rabaul for the Port clearance at the arranged time the following morning.

## 3.4 Arrival in the Search Area / Rabaul – Monday, 18 December 2017

The ship entered the southeast corner of the search area at 0730 and turned to the west for the passage into Simpson Harbour, Rabaul, arriving at 1020. While awaiting the arrival of port clearance officials, *Fugro Equator* held a stopped position using the Dynamic Positioning (DP). The weather improved, despite a gusty northwest wind, the earlier showers cleared away to broken cloud.

**Figure 3 – The 2017 *AE1* Search Team Photograph, L-R: LEUT James McPherson, Roger Turner, Peter Briggs, Paul Hundley, Magnus Windle (Fugro), Chadran Karapiah (Fugro), Gus Mellon, Nigel Erskine and Irini Malliaros**

MBES and Sub Bottom Profiler (SBP) data were collected *en route* to Rabaul; by way of confirmation, the MBES data agreed precisely with the MBES data collected in the same area during Find *AE1*'s expedition in November 2015.

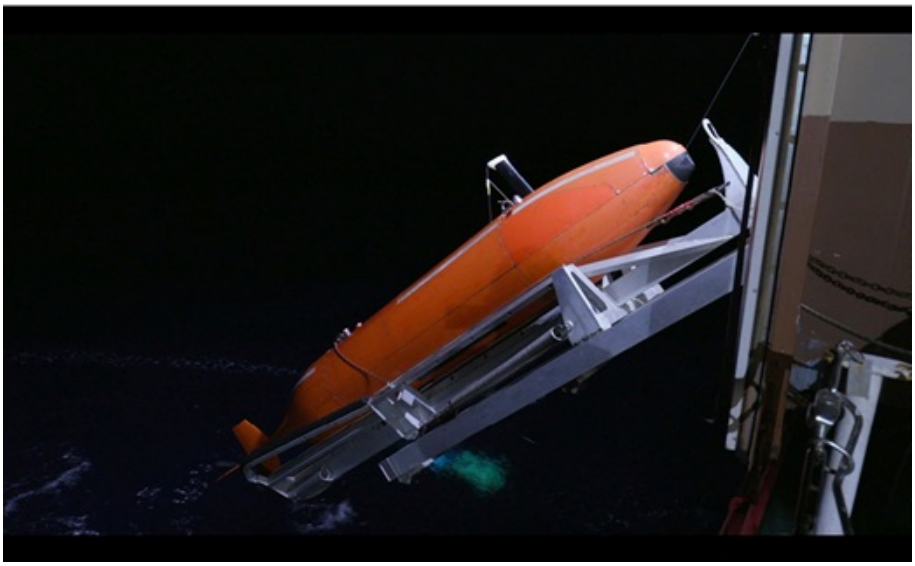
After clearing Rabaul, *Fugro Equator* resumed the MBES survey at 1414, heading east and then turned northeast, to the northern end of Area A, where it arrived at 1915 on Monday, 18 December. This completed the MBES survey of Area A. The MBES survey provided an accurate profile of the sea floor, which could be loaded into the AUV. This allowed the AUV to fly just 40m off the seafloor, where its onboard sonars were most effective, to conduct the sonar search for the wreck.

A sound velocity profile was obtained, to allow corrections to be applied to the various sonar devices used for the search.

**Figure 4 - Preparation of the AUV for Mission 01**

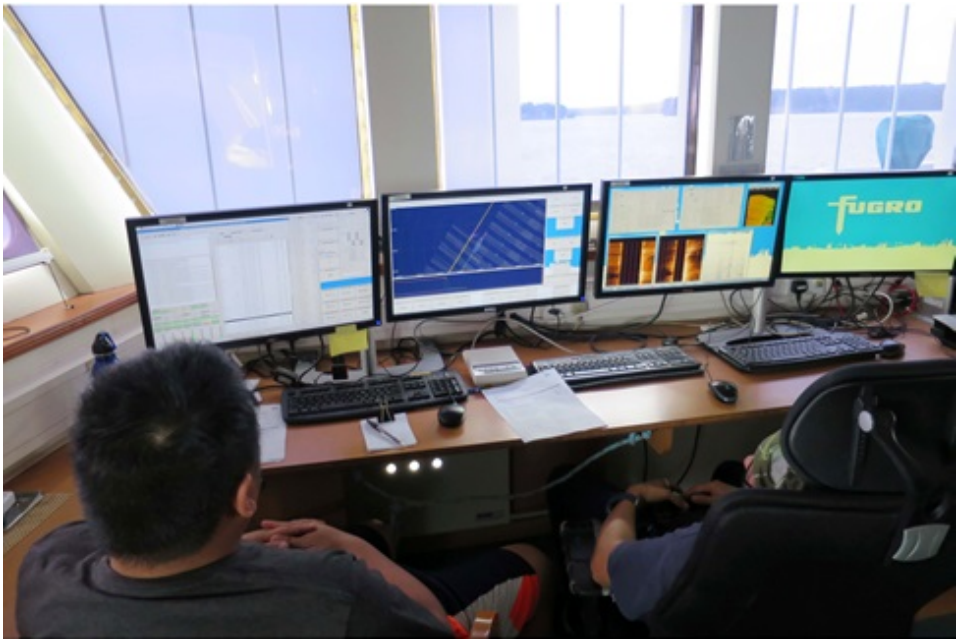
Having programmed the MBES acquired bottom topography into the AUV; Mission 01 was launched at 2325 to search the inshore half of Area A. The AUV would gradually work its way inshore with a 150m line spacing. The seabed topography of the northern end of the area proved challenging for the AUV, requiring steep climbs and descents to remain 35-40 metres off the seabed. Strong currents were also experienced at the northern and southern ends of each survey line. *Fugro Equator* cruised slowly along at three to four knots; maintaining station within 500 metres of the AUV and relaying precise geographical coordinates to it via an acoustic link. The wind blew Force 3 from the northwest, with occasional sharp, thundery showers adding to the challenge of maintaining the ship's position.

**Figure 5 - Launching the AUV for Mission 01**



The control team monitoring the AUV operations via an acoustic data link watched anxiously lest the AUV exceed its limits for climbing/descending or propulsion load against the strong currents. Either scenario could cause it to abort the mission. Happily, the AUV continued untroubled and completed the mission at 1740 on Tuesday, 19 December, being due for a battery recharge. It was recovered at 1916, shortly after sunset.

**Figure 6 - AUV Control Room at Rear of Bridge**




Meanwhile, the results *from Fugro Equator*'s MBES runs were evaluated, generating three Category 1 contacts (FE-01 – FE-03 respectively). The project's contact classification regime is described in Annex C.

## 3.5 Possible *AE1* Contact

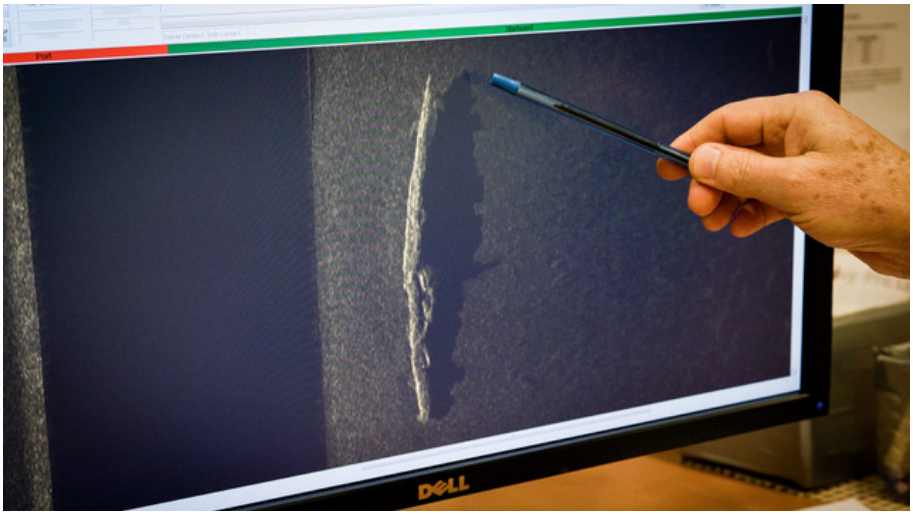
The AUV Mission 01 data was downloaded and the data processing and evaluation commenced as the AUV was prepared for Mission 02. At around 2120 on Tuesday, 19 December, the Expedition Team were summoned to the Processing Room, to view a sonar contact obtained in the first survey line of Mission 01. This line had been completed by the AUV within two hours of survey's commencement.

**Figure 7 - Processing Room**

As the team entered the processing room, the exultant smiles and sense of excitement of the two analysts were infectious. A contact had been detected by the AUV's side scan and multi-beam echo sounder sonars. The contact, identified as FE-04, was lying proud of a hard, flat seabed and exhibited a regular, long, narrow rectangular shape consistent with *AE1*'s dimensions.

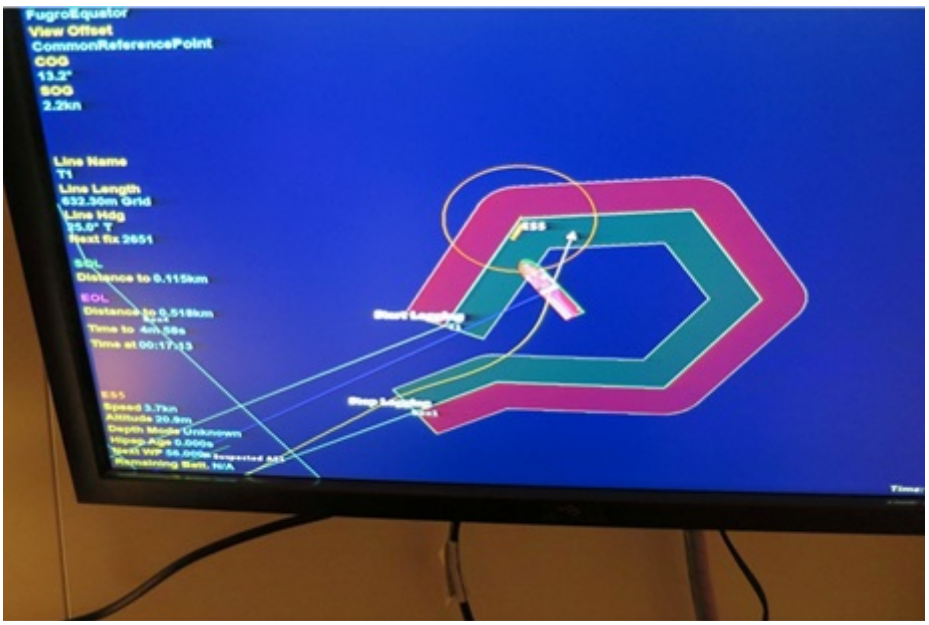
Further processing revealed that the long axis of FE-04 was aligned to the southwest. A long, linear sonar shadow extended upwards from the centre of the contact and offered the tantalising possibility that it was a periscope. On the presumption this was indeed a submarine, the imagery that would correspond with the forward and after casings were irregular and inconclusive, but vague acoustic returns hinted at what may have been the flat surfaces of the submarine's forward and after hydroplanes.

**Figure 8 - First Contact FE-04, Ultimately Identified as AE1**



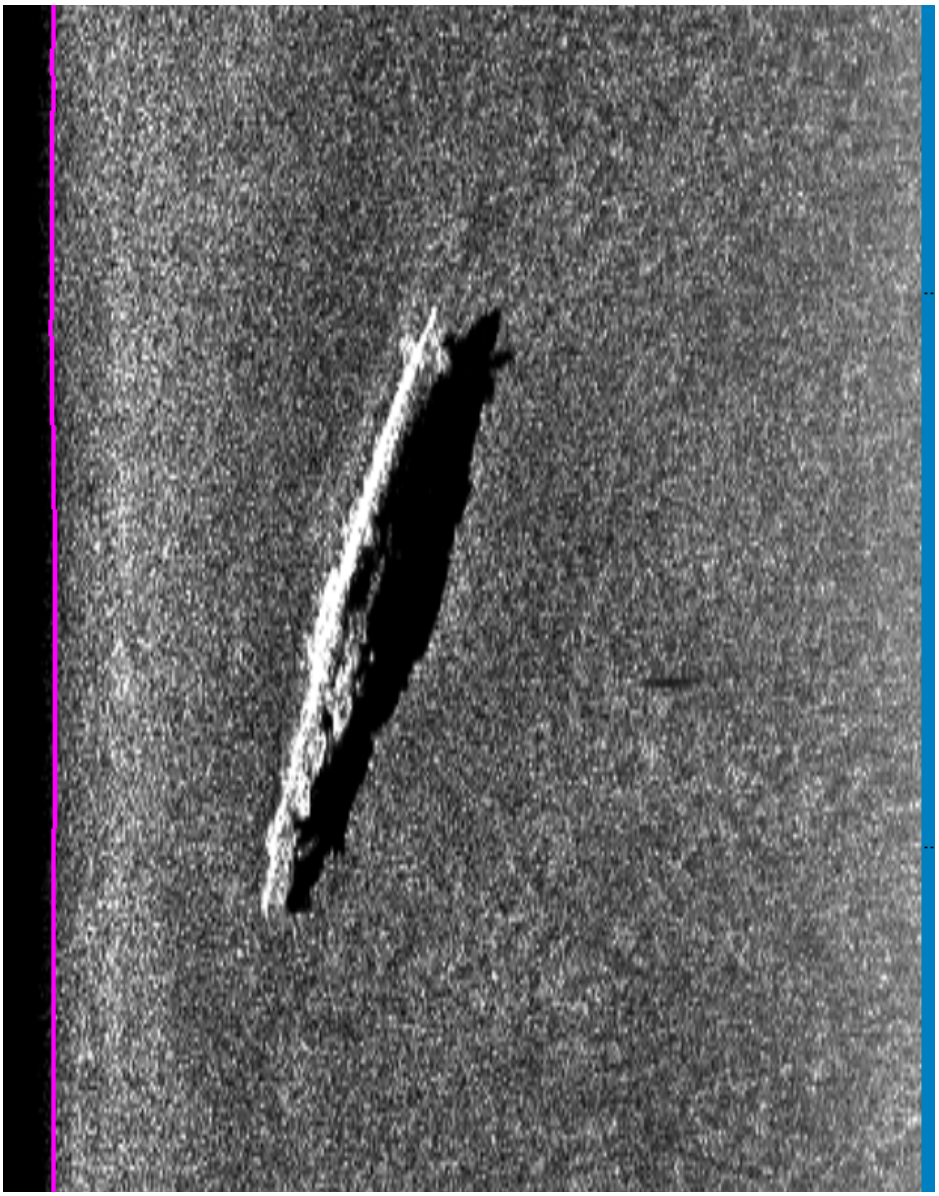

In consultation with the Party Chief, the decision was made to change Mission 02 to a detailed AUV examination of FE-04. This comprised several closely spaced passes over the wreck site to improve the sonar definition and obtain different perspectives from crossing runs. This took account of the fact that, under certain circumstances, acoustic imagery can present with strong aspect dependencies. Upon completion of this task the AUV resumed searching Area A until surfacing for recovery at first light, (0600) on 20 December. The AUV was launched for Mission 02 at 2330.

**Figure 9 - AUV (Indicated as ESS) Tracking During Investigating of Contact FE-04**



The AUV was recovered at 0720 the next day and the data was available at approximately 0830. The new data further affirmed the submarine-like features of the contact, including the hydroplanes.

**Figure 10 - Refined AUV Sonar Image of FE-04**



Based on the compelling imagery acquired from both missions, the decision was made to suspend the search and conduct a drop camera inspection of FE-04.

## 3.6 The Men of *AE1* have been Found

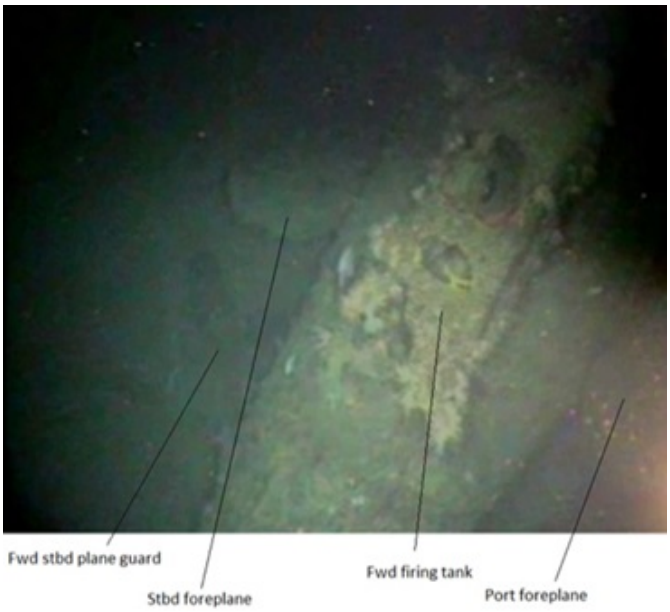
The STR[7] Seabug Drop Camera consists of a metal framework, fitted with vanes to provide some heading stability in a current, along with lighting and colour video and stills cameras. Still shots can be taken on command and are coordinated with a strobe flashlight. The Drop Camera provided overhead, real-time video imagery to the control room sited just off the working deck aft; ship movements were coordinated by UHF radio link to the bridge. The Drop Camera's position was tracked by an acoustic tracking system showing its position relative to *Fugro Equator.* This enabled the camera array to be manoeuvred to better aim the camera while the ship was held in position by its dynamic positioning system.

[7] http://www.str-subsea.com/sales/sea-bug-drop-camera-system

**Figure 11 - Drop Camera Deployment**

The ship was manoeuvred to position the camera close to the southwestern end of Contact FE-04. The camera obtained visual contact with the bottom at 1052, 37 minutes after it began the 300-metre descent to the site. The ship's position was slowly adjusted to bring it over the top of Contact FE-04 and the first video imagery showed a narrow, man-made shape, with what appeared to be the starboard forward hydroplane in the foreground. As the camera moved across the wreck site, the port forward hydroplane came into view. Brief discussion among the Expedition Team followed, and all quickly agreed that the camera was positioned above *AE1*'s bow. Both hydroplanes appeared to be at the "hard to rise" position, which truncated their overall appearance when viewed from overhead by the drop camera.

**Figure 12 - First Sighting of AE1 - The Forward Starboard Hydroplane**




*Fugro Equator* was manoeuvred so that the Drop Camera gradually moved aft along the starboard side of *AE1*. The keyhole overhead perspective provided by the video camera yielded some confusing shapes and shadows – the submarine's surviving hull showed signs of extensive damage and the fin, when it came into frame out of the gloom, was out of position and listing at a strange angle. After some time examining the stern, sighting the after hydroplanes and port screw, the camera was then moved forward along the port side of the pressure hull. It was here that the team observed that the fin (the casing that contains the conning tower) was torn from its footings and angled over to starboard.

**Figure 13 - AE1's Dislodged and Damaged Fin**

If there were any doubts remaining about the identity these were banished by the sharp images of the features of the fin, bridge and bridge helm positioned on the forward periscope standard. The Drop Camera serial finished to a round of applause and sighs of relief in the control room –*AE1* and its crew had indeed been found. The lights of the Drop Camera were the first rays to illuminate the submarine since that fateful day, 14 September 1914.

News of the discovery was passed to the RAN, ANMM and Silentworld Foundation (Annex D refers). A brief commemorative service, attended by the Survey Crew and Expedition Team was held over the wreck site.

**Figure 14 - Commemorative Service**

After some discussion between the Party Chief and Fugro's shore-based project manager the decision was made to deploy the AUV and undertake an AUV photographic mission. This was conducted overnight, launching the AUV at 2156 and recovering it at 0058 on 21 December. The AUV passes provided more than 6,000 high-definition overhead black and white images. As the Expedition Team travelled back to Australia these were combined by the Fugro shore support team to form an impressive, 2 Dimensional (2D) photomosaic (Annex E refers).

*Fugro Equator*'s daily Operations Reports are included as Attachment 12.

# 4 Post Search

## 4.1 Initial Impressions

Having found *AE1*'s wreck site, the Expedition Team began to ponder the circumstances that led to the submarine's loss. The team's considered opinions, based on a critical review of the sonar data, drop camera footage and photomosaic imagery, are outlined in Annex E.

Firstly, limitations of what can be gleaned from available data must be appreciated:

- This is a complex shipwreck site that exhibits extensive damage due to *AE1*'s initial sinking event and natural processes that have occurred in the wake of its loss. Consequently, isolating the precise cause(s) of the submarine's loss may not be possible.
- Fugro's drop camera was an excellent instrument, with colour video and still cameras and lighting.
- *Fugro Equator*'s Marine Crew and Survey Crew demonstrated great skill in positioning the drop camera over the wreck site and manoeuvring the ship to move the camera. This was no easy feat, given that the drop camera was suspended in current on a single cable/tether at a depth exceeding 300 metres.
- However, it should also be noted that the drop camera rig by its very design is restricted to providing overhead imagery and isolated "keyhole" views of relatively small areas of the wreck site. Further, the drop camera's manoeuvrability is dictated entirely by the movement of the survey vessel and, unlike a remotely-operated vehicle (ROV) is incapable of independent movement (in horizontal, vertical and lateral planes), including the ability to hover and pan over specific areas for an extended duration.
- The AUV-generated photomosaic has provided a very useful overview of the wreck site; however, these images are also only from an overhead (plan view) orientation and do not depict the hull in profile. Further, the photomosaic images are black-and-white, which limits their interpretive capacity (e.g., the ability to distinguish and identify areas of active corrosion or surviving paint).

Given the aforementioned preconditions, it should be appreciated that any conclusions regarding the cause of *AE1*'s loss must be qualified. However, the Expedition Team has now reached consensus regarding the most logical loss scenario based on the information available and believe the root cause was a diving accident:

- *AE1* was probably dived or diving when the accident occurred. This conclusion is based on the observation that the submarine's fin guardrails are in the stowed position and the upper conning tower hatch appears to be shut.
- The wreck site's position is consistent with a return course to Rabaul.
- Both of the submarine's forward and after hydroplanes appear to be in the "hard to rise" position, which indicates the submarine was endeavouring to return to the surface when it was lost[8],[9].
- It appears that the submarine experienced a depth excursion and exceeded its crush depth.[10] This resulted in implosion of the hull forward of the fin that would have completely destroyed operational stations within this part of the submarine, including the control room and forward torpedo compartment. This is based on obvious collapse/flattening of *AE1*'s hull structure forward of the fin. By contrast, the approximate stern half of the hull appears to be largely intact and retains its original three-dimensional form.
- Implosion may have contributed to initial dislodging of the fin from the pressure hull.
- In the moments following implosion, the remainder of the submarine flooding explosively. This may have dislodged the engine room hatch, which is noticeably absent.
- The flooded and partially destroyed submarine sank rapidly to the seabed and probably landed on its keel.

[8] *AE1*'s forward hydroplanes leading edge are angled up, providing positive lift to the bow and submarine overall. The after hydroplanes control the aspect of the submarine, bow up or bow down. *AE1*'s after hydroplanes leading edge is angled down, resulting in an effort to lift the bow. A bow up angle on the submarine will cause it to head towards the surface. Hence, both hydroplanes are said to be "hard to rise".

[9] The hydroplanes are operated by electromechanical motors in the control room, driving through rod gearing to a worm gearing at the hydroplanes and would be most unlikely to assume this angle involuntarily or under the force of the various impacts.

[10] Depth excursion - an uncontrolled depth increase. Crush depth – the depth at which the pressure hull fails.

- The hull maintained a moderate bow down angle [15-30 degrees] as it descended through the water column as the bow torpedo tube is relatively undamaged, but ultimately pitched forward on striking the bottom, as illustrated in Figure 18.
- The impact of the bow against the seabed probably generated a "whiplash effect" that caused the dislodged fin to hinge forward and pivot around the forward edge of the join between the upper and lower conning tower sections. This is evidenced by the current position of the fin (Figure 21). It is also possible that the implosion commenced this process.
- In all likelihood, there was little sedimentation to cushion the submarine's collision with the bottom. This is based on the current appearance of the seabed surrounding the surviving hull, which is hard, flat, and appears to be regularly scoured by strong, seasonal currents.

Graphics Artist, Grant Gittus has developed an illustrated sequence to explain the sinking process as envisioned by the Expedition team.

**Figure 15 - Graphic Sequence of Sinking Process – Dived, with heavy trim trying to return to the surface, Hydroplanes "hard to rise"**

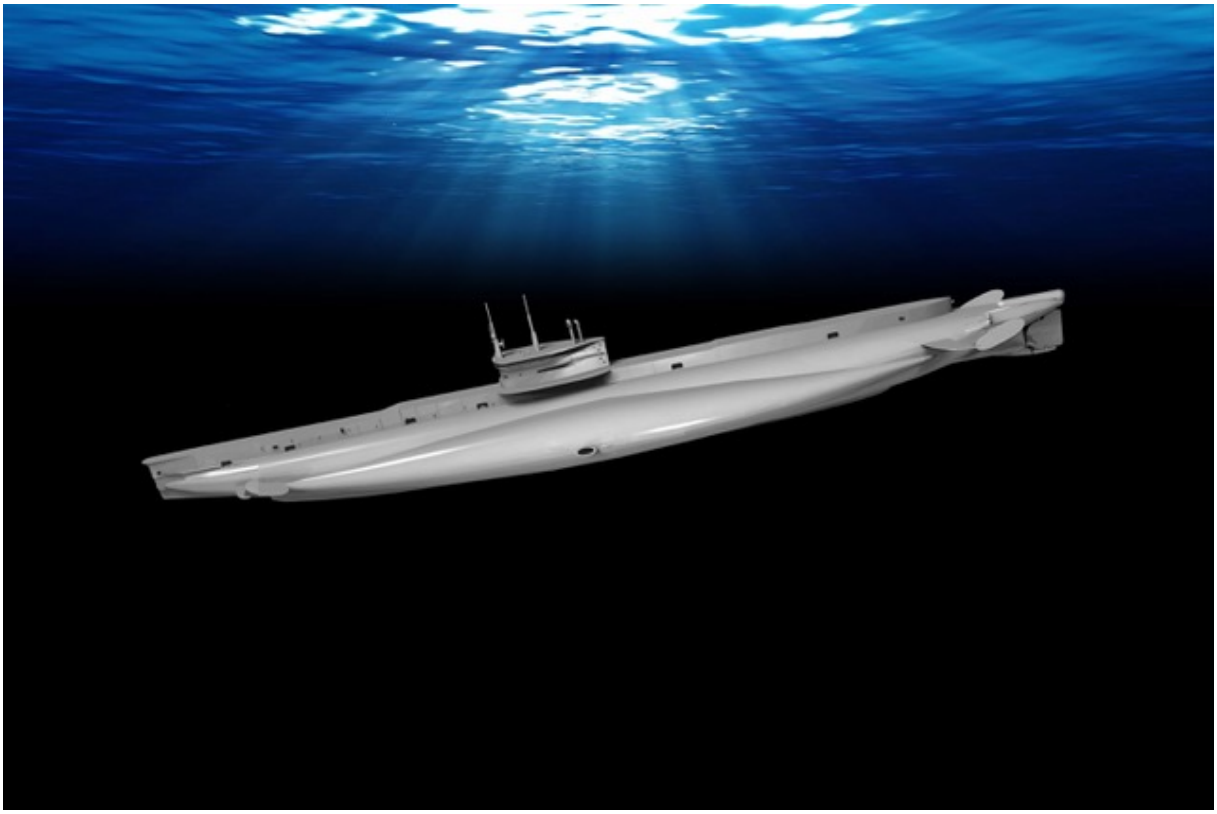
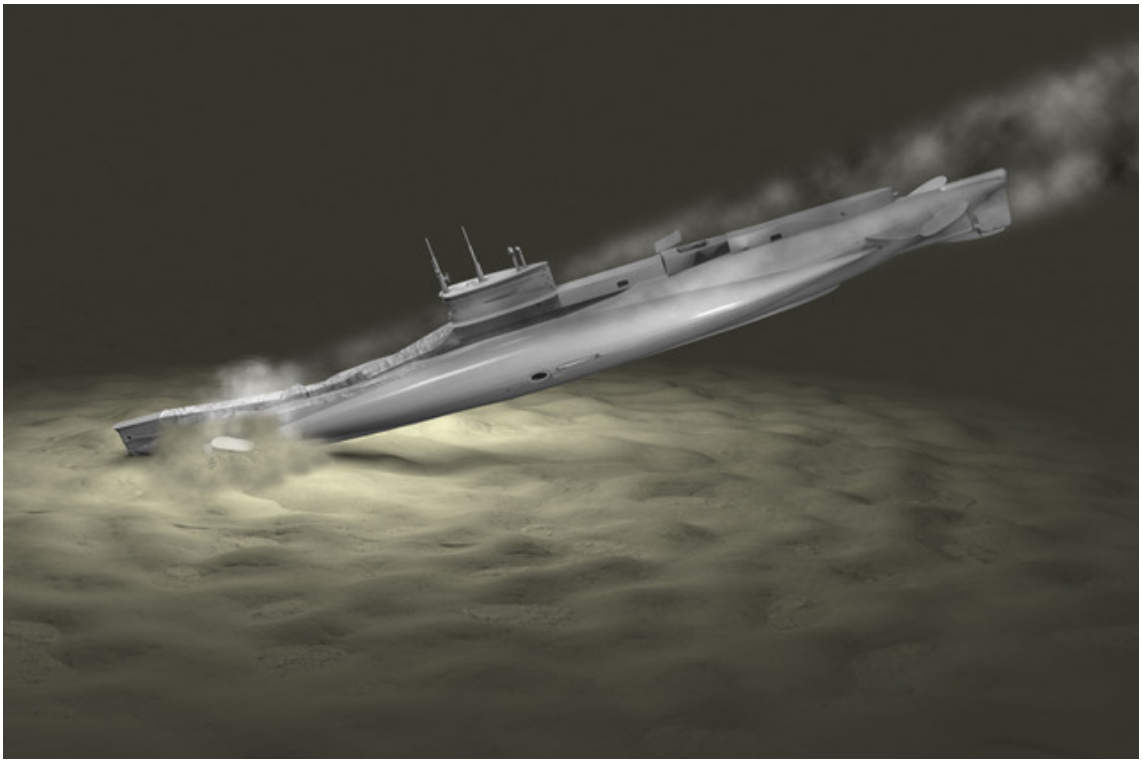


**Figure 16 - Graphic Sequence of Sinking Process – Implosion as SM Exceeds Crush Depth**

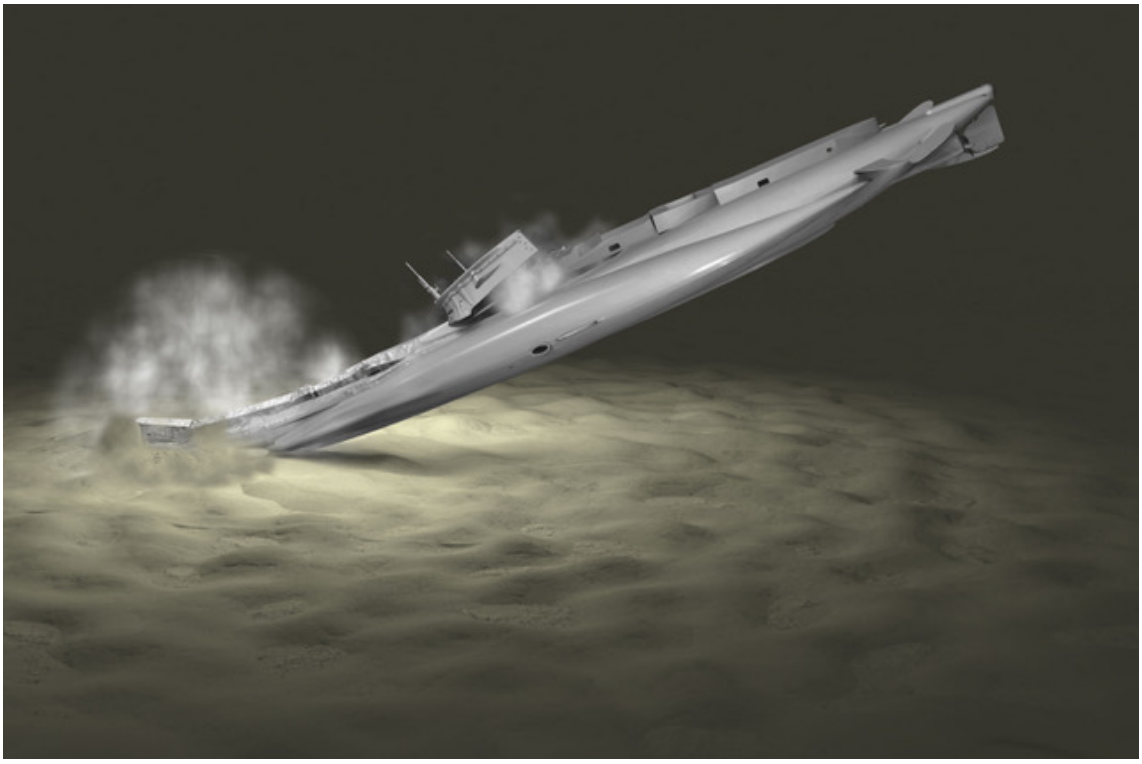
The hull over the control room and forward torpedo compartment implodes and instantly floods with great force. As the implosion's pressure wave moves aft, it blows the engine room hatch clear of the submarine. The crew are killed instantly. The fin movement forward may have commenced at this point.

**Figure 17 - Graphic Sequence of Sinking Process – Initial Impact**



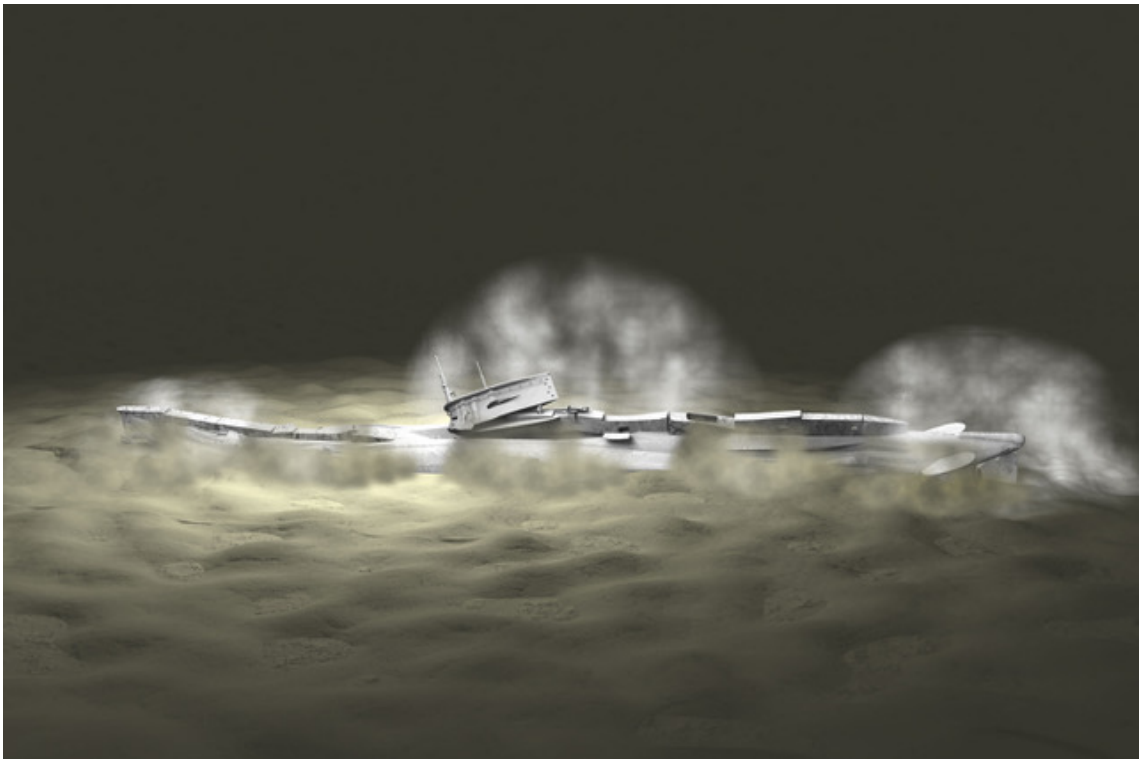
The flooded submarine sinks rapidly and gathers speed as it plunges towards the seabed. The hull strikes the bottom at a 10-to-20 degree bow down orientation and absorbs the impact on the leading end of the keel.

**Figure 18 - Second Impact, Pitch forward, whiplash effect on Fin**



It is probable that the momentum from the initial impact carries the submarine forward and cause the bow to strike the bottom a second time. This generates a "whiplash effect", completing the dislodgement of the fin, which hinged forward, possibly on the leading edge of the seam in the conning tower. The fin ultimately comes to rest in the debris of the submarine's forward casing.

**Figure 19 - Third impact, Submarine settles heavily back on Keel**



Gravity causes submarine's hull to fall back towards the seabed. It is plausible that the force of *AE1*'s keel striking the bottom probably dislodged the hydroplane guards, which fall away and land on the seabed just beneath their normal mounted positions on the hull. [11]

**Figure 20 - Conning Tower Upper Hatch Shut**

**Figure 21 - Conning Tower Wheel and Ladder Revealed by Fracture of Conning Tower**

[11] It is possible that this is the result of corrosion causing the failure of the securing arrangements. The Expedition Team consider this less likely given the consistent failure of all four guards, displacement of the port after hydroplane guard and continued integrity of *AE1*'s sister submarine's *AE2's* hydroplane guards.

Corrosion of *AE1*'s metallic components, in concert with other natural processes (such as biological activity, currents and sediment scouring), have no doubt had a detrimental effect on the wreck site. In the worst cases, these processes have probably contributed to structural damage to the hull and had a negative impact on the preservation of organic and non-organic artefacts and features.

**Figure 22 - Ruptured Pressure Hull Plate Damage Forward of the Fin**

Pressure hull (riveted) plate rupture over main switchboard

It is worth noting that any attempt by *AE1*'s crew to recover from the initial accident that caused the submarine's depth excursion would have been complicated by the fact that only the port propeller shaft was operable when the loss occurred.

- This is based on archival information that states *AE1*'s starboard engine clutch was "jammed in". The clutch's disabled state prevented the starboard electric motor from being used to go astern on the surface or while the submarine was submerged.[12]

The location of the wreck site, which is clear of Mioko Island and on the most likely route back to Rabaul, strongly suggests that the accident occurred during a routine training dive.

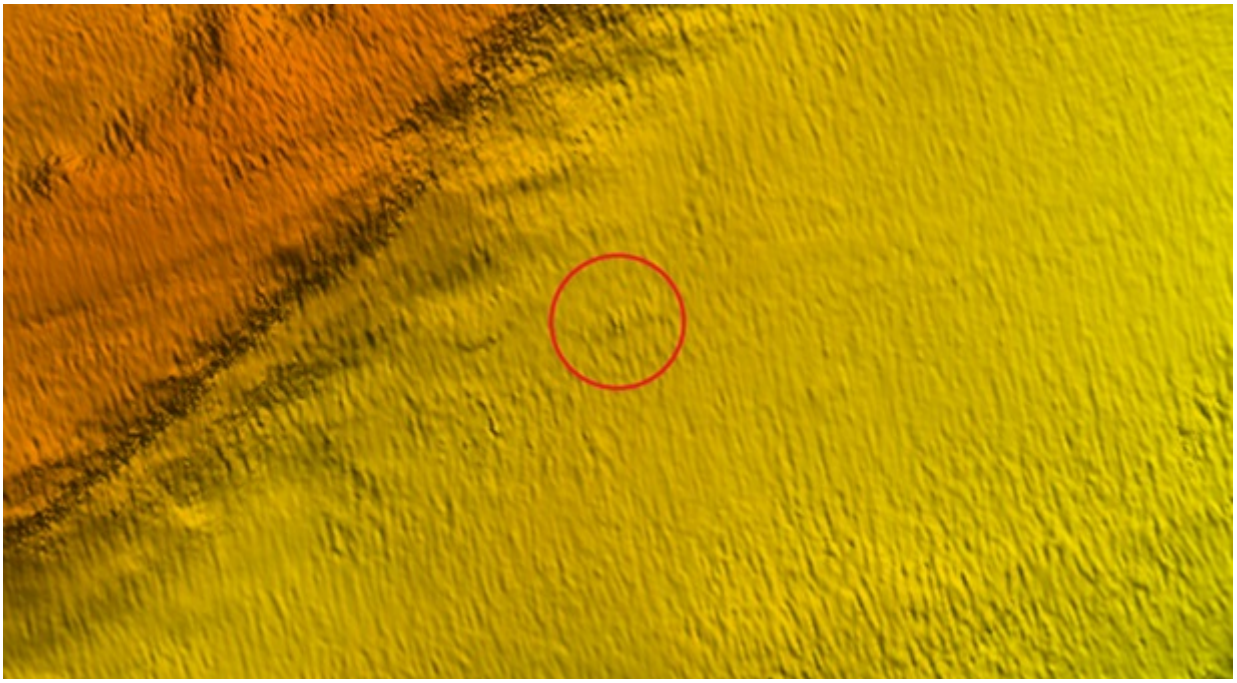
All available evidence indicates that, when the end came for *AE1*'s officers and ratings, it would have been very quick, or more likely instantaneous. Whilst it appears the crew initially struggled to regain the surface as the accident unfolded, the final sinking event, hull implosion and subsequent flooding would have been very rapid and ultimately fatal.

## 4.2 The 2015 Multi Beam Echo Sounder Search Re-Analysed

MBES data gathered during Find *AE1*'s November 2015 survey has been re-analysed by Fugro using current software—and the benefit of hindsight based on current knowledge of the location of *AE1*. An inconclusive acoustic contact is present at the known location of the submarine (see Figure 23 below).

[12] *AE1* Search Report dated 11February 2012, http://findae1.org.au/reports/ae1-search-report-2012/, section 3.5

**Figure 23 - Inconclusive Detection of AE1 during November 2015 Search from Fugro Analysis**



## 4.3 The Return to Australia

*Fugro Equator* returned alongside at Rabaul at 0745 on Thursday morning, 21 December and landed the Expedition Team and Fugro Survey Crew. The Fugro personnel departed by air that day, whilst the Expedition Team travelled by road to the Rapopo Plantation Resort, Kokopo. The resort's diving boat was then used to transport members of the Expedition team to Mioko Island to present educational and sporting packages, funded by the SWF to residents of the Island.

- The boat and its coxswain, an ex-RAN ship's diver, were well suited to the task.
- The coxswain's familiarity with the local dignitaries facilitated arrangements.
- These gifts were very well received.

**Figure 24 - Rabaul Kokopo Dive Boat (Image: Gus Mellon)**

**Figure 25 - Handing over of Educational and Sporting Packages (Image: Gavin Cathcart)**

The Expedition Team departed by air for various Australian destinations am Friday 22 December 2017.

## 4.4 Follow up Examination

On balance, the Expedition Team has determined that any additional information that might be gleaned from an internal examination of *AE1* does not warrant a dedicated expedition, particularly as any such examination would disturb the wreck site's sanctity as a grave site. An ROV examination would undoubtedly add to the overall picture of what led to the submarine's loss, but is unlikely to address key gaps in our knowledge of the root cause(s) of the initial accident/depth excursion, given that:

- The main vents sighted in the control room of the wreck of *AE1*'s sister-submarine, *AE2*, have no indicators showing whether they are open or shut. With this in mind, it is highly unlikely that the position of *AE1*'s main vents could be determined by sighting the hand wheels.
- Visual inspection of the main vents in the control room would be difficult due to the amount of damage and debris present in this area.
- It is currently not known whether *AE1*'s engine clutches featured indicators that showed whether they were engaged.
- If no indicators are present on the engine clutches, then the quadrant at the foot of the clutch operating hand wheel shaft in the Engine Room bilges would have to be inspected in order to determine the position of the clutch. This area would be extremely difficult to access with an ROV.
- Based on the aforementioned, the case for a dedicated and comprehensive ROV examination of *AE1*'s interior hull cannot be justified.
- In addition, any follow up examination would likely reveal the location of the site – a cause for concern, given the interest in *AE1* now being shown by amateur and non-archaeological groups.

ANMM's Curator of RAN Maritime Archaeology, Dr James Hunter, has advised that, based on his past experience working on the archaeological investigation of the wreck of *H.L. Hunley*[13], there is an extremely high potential for skeletal and other human remains to be preserved within an enclosed structure such as *AE1*. Further, he has advised that any internal ROV examination should be conducted in a manner that does not disturb the site and its associated human remains and archaeological material, and only undertaken if a determination of what caused the submarine to enter its fatal dive is guaranteed.

It is worth noting that *AE1* differs from *H.L. Hunley* in that the latter's pressure hull has developed much larger openings to the sea since its loss. With this in mind, a balance could be struck between disturbing the site and obtaining useful information, and therefore justify penetration into one or more of the submarine's internal spaces.

A circular hole was observed in Number 6 main ballast tank and may warrant follow up examination. The hole is believed to be a corrosion feature (see discussion in Annex E) but is almost perfectly circular in form and outwardly resembles penetration damage caused by an artillery shell. For this reason, the Expedition Team feels this feature should be examined in greater detail.

**Figure 26 - Circular Hole in Number 6 Main Ballast Tank**

Any follow-up examination should also collect environmental information, corrosion potential data, and measurements of surviving hull components (with particular emphasis on hull plate thickness) to determine the submarine's natural rate of deterioration. These data will assist current and ongoing efforts to manage and protect the site. Given the site's depth, and the characteristics of prevailing currents and other sea conditions in the area, both work-class and observation-class ROVs would be necessary to ensure successful collection of imagery and other data.

## 4.5 Descendant Response

Descendants of *AE1* crewmen were kept apprised of events as the project progressed. Ken Greig, Find *AE1*'s Company Secretary, maintained communications with relevant individuals and organisations.

Informal feedback from descendants is supportive of future examination of the wreck site, including an inspection of the interior hull (if warranted). Descendants also greatly appreciated a brief commemorative service held by the Expedition Team and *Fugro Equator* crew that was held over the site following its discovery. Ongoing updates and advice of the successful outcome of the search ahead

[13] H.L. Hunley was a human-powered submarine of the Confederate States of America that was lost during or immediately following an attack that sank the Union blockade ship USS Housatonic near Charleston South Carolina. It was found in 1995, and recovered in 2000. Archaeological investigation of the submarine and what led to its loss is ongoing.

of the official media release was also greatly appreciated by descendants. The formal response by [need full name of organisation here] has been heartfelt and heartening. A poignant letter of appreciation that appeared in the [full name of organisation here]'s latest Newsletter are featured in Attachments 12 and 13.

Political cartoonist Mark Knight of the *Herald Sun* newspaper expertly captured the collective sentiments of those aboard *Fugro Equator*.

**Figure 27 - AE1 Cartoon, Home for Christmas (Image: Mark Knight)**


## 4.6 Media Management

The agreed media strategy, as coordinated by the RAN, was to maintain a low-key approach to the deployment and survey. The decision was made by the Expedition Team Leader to not provide daily reports from the search ship—a strategy intended to avoid overloading *Fugro Equator*'s communications bandwidth and limited capability to service media requests, as well as maintain the confidentiality of the wreck site's location in the event it was found. This created a muted sense of anticipation that was augmented by relevant background stories that simultaneously ran in print media. ANMM experts spoke to the media in Sydney and provided impromptu "talking heads" to discuss *AE1*'s history and the technology used to search for the submarine for print and radio. This became more difficult as individuals involved with the project departed for the Christmas/New Year holiday. Interest in the deployment was underestimated due to late notice of financial contributions to Silentworld Foundation from NewsCorp. In hindsight, the requirement for an adequate media response should have been anticipated and a more structured arrangement established to meet this need.

The Minister for Defence reported *AE1*'s discovery at a media conference held at 1100 on Thursday, 21 December 2017. The announcement was supported by a package of video and still photographs that was quickly distributed by all national media and soon thereafter picked up by several international media outlets. RAN media has provided the following summary of the project's coverage:

*"An analysis of coverage using iSentia's media monitoring tools shows the month 4 Dec 17 to 5 Jan 18 produced 394 media items and almost 2,000 tweets in the Australian market.*

*This coverage reached a cumulative audience of 33,834,295 with an equivalent advertising space rate of $2,485,826. 86% of this reach was on the day of the announcement.*

*This means many Australians saw the material multiple times and the penetration is approximately four to six times what we would normally see for a major announcement.*

*The extensive coverage was no doubt a result of the quality of the images captured from the drop camera and vision package compiled by Bayden Findlay. As expected, the vast majority of audience reach was from free-to-air television and their associated social media accounts.*

*These figures do not include Facebook or international reporting, which notably includes BBC, New York Times, Washington Post, CNN, and Fox News.*

*A Google News summary shows over 6,500 news items were generated on AE1 in the month but given the size of those markets and the tools we have available, it is not possible to estimate the audience size. Regardless, it would be very significant."*

The presence of a cameraman and a Navy media adviser in the Expedition Team was extremely beneficial and ensured a high level of images and media advice for the preparation of speeches etc.

## 4.7 Future Memorials & Commemoration

The Bita Paka Commonwealth War Cemetery at Kokopo has memorials to those lost aboard *AE1*. They include a copy of the bronze plaque created by Dr Ross Bastiaan and installed at the RAN Heritage Centre on Garden Island. It would be appropriate to add to these memorials information about *AE1*'s wreck site and its designation as the final resting place of the submarine's crew.

A smaller, secondary memorial plaque could also be erected on Mioko Island if resources allow and local approval is obtained.

- It is likely that the descendants, who are able to do so, would wish to visit the closest commemorative site.
- This would have a secondary benefit of further developing the ongoing association between *AE1* descendants and the Mioko Islanders – see the discussion below regarding protection of the wreck site.

Access to Mioko Island is via a 30-to-40 minute boat trip from Kokopo (the Rapopo Plantation Resort dive boat was used by the Find *AE1* team), and involves a beach landing (there are no available wharf or jetty facilities on Mioko Island). It is a remote area, with minimal infrastructure apart from two local villages.

**Figure 28 - Mioko Island Beach Landing Site, 21 December 2017 (Image: Gavin Cathcart)**

## 4.8 Protection of the Shipwreck Site

Find *AE1* notes that *AE1* is a submerged cultural heritage site that represents the shared heritage of Australia and Papua New Guinea.

Find *AE1* and its Project Partners understand that *AE1*'s wreck site and all of its associated artefacts and features represent a Sovereign vessel that remains the property of the Australian Government. It is also understood that *AE1* lies within the territorial waters of Papua New Guinea and therefore management of the site is a joint responsibility between both Governments[14].

Whilst no specific underwater cultural heritage legislation exists within PNG to give legislative protection to *AE1*'s remnants, overall responsibility for the site rests with the PNG National Museum and Art Gallery[15], which acts as the nation's responsible entity for managing cultural heritage sites.

Available evidence strongly suggests that *AE1*'s surviving hull contains the remains of the submarine's crew of 35. Whilst it is understood that the site is not an official "war grave" as defined by relevant legislation[16], the Australian and international public would regard the site as such and expect that proper respect and protection of the crew's remains are paramount going forward.

Given the mix of crewmen originating from United Kingdom, Australia and New Zealand, the appropriate interests of all relevant governments (Australia, New Zealand and the United Kingdom) in the site's proper management and sanctity as a war grave is also noted. Both New Zealand and the United Kingdom should be included in ongoing discussions regarding current and future archaeological investigations of *AE1*, as well as management strategies and guidelines established to ensure the long-term protection of the site and its associated human remains.

There is a common need to protect the site against unsanctioned interference and all future efforts to investigate and preserve *AE1* must be coordinated by a mutually agreed upon and sanctioned overriding authority. The existing *AE1/AE2* Inter-Departmental Working Group (IDWG) provides a tried-and-tested whole-of-Government coordination vehicle that is eminently suited to this task. Find *AE1* will continue to cooperate fully with the IDWG in partnership with ANMM.

From a practical perspective, the Mioko Islanders have a clear view of the wreck site's location and could provide warning of any unsanctioned attempts to interfere with it. The island has mobile phone connectivity, and arrangements could be made with one or more designated "wreck spotters" to notify NMAG of any unusual activity. Similarly, the Rapopo Plantation Resort, which is situated on the waterfront at Kokopo, enjoys distant, but clear, views of the site. The resort's dive shop operator is an ex-RAN sailor who is frequently operating in the area aboard the resort's dive boat and may be prepared to monitor the site and provide warning of illicit activity.

A summary of recommended steps to protect the wreck site is included in Annex F.

## 4.9 The Oceanographic Environment of the Wreck Site

Dr Ian MacLeod has undertaken an initial analysis of the oceanographic environment at the wreck site using data gathered by the AUV, (Annex G refers).

Further data collection should be undertaken during any follow up examination to provide a more comprehensive and accurate assessment of its situation and likely longevity. As the site is subject to seasonal, strong ocean currents these will need to be taken account of when planning any subsequent archaeological activities.

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[15] In 1997, Papua New Guinea ratified the UNESCO World Heritage Convention of 1972 and became a State Party. At that time, the Minister responsible for the Department of Environment and Conservation endorsed that Convention which enabled the Department as the focal point for preservation and conservation of heritage matters in the country. The National Museum & Art Gallery is part of the Ministry of Culture and Tourism. The National Museum & Art Gallery was established to preserve, protect and promote Papua New Guinea's cultural heritage.

[16] https://www.dva.gov.au/commemorations-memorials-and-war-graves/office-australian-war-graves.

# 5 Conclusions & Recommendations

The final resting place of the *AE1* and its crew has been found.

Understanding exactly what befell them is limited by the location of the wreck site (at considerable depth within a foreign nation's territorial waters) and damage to the hull and its associated artefacts and features caused by the passage of time. Despite these limitations and challenges, examination of acoustic, video and still imagery acquired during the 2017 survey has provided a reasonable level of understanding of the probable cause of the submarine's loss.

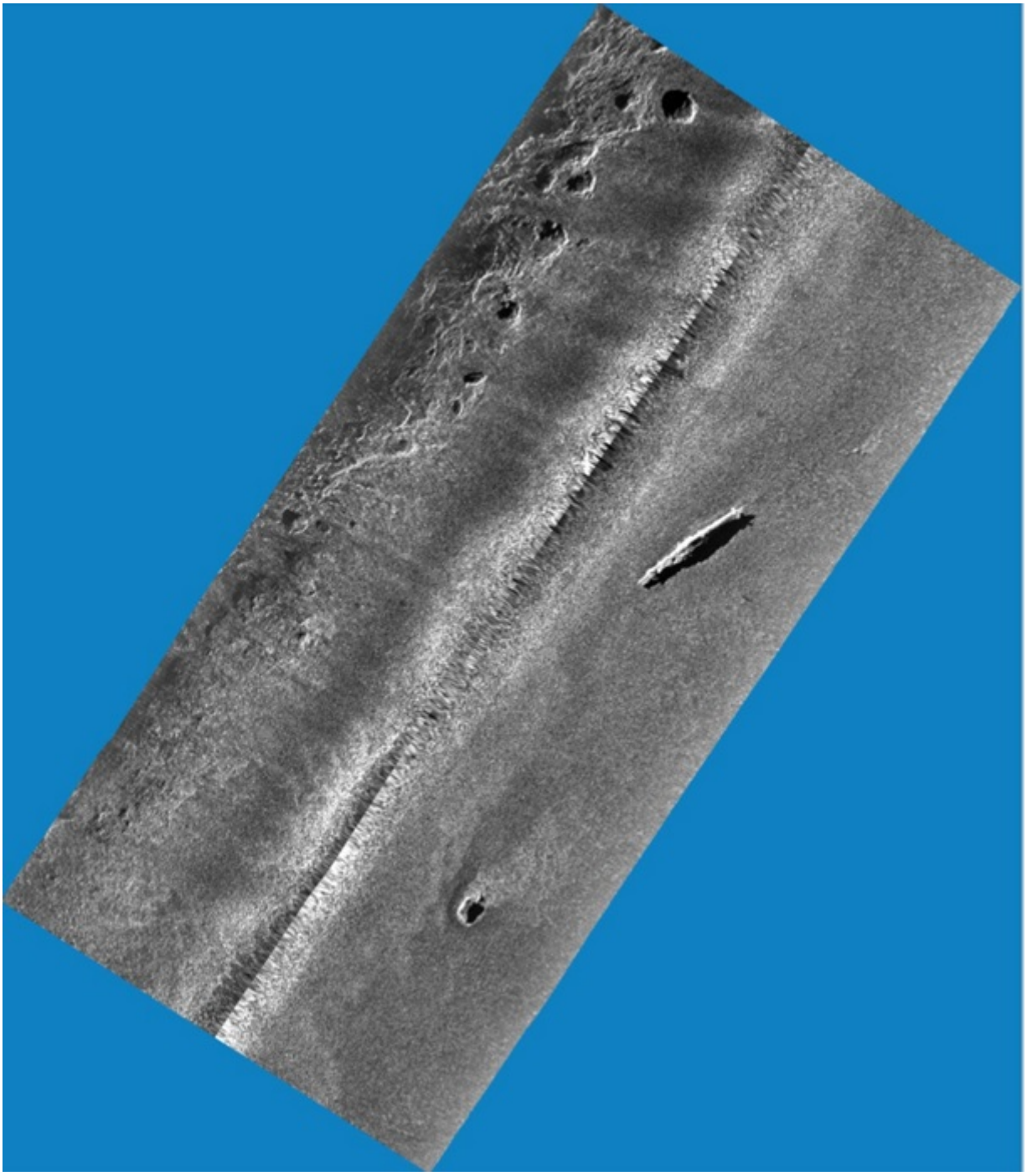
A follow-up archaeological survey of *AE1*'s external hull is recommended, with the stated goal of producing a detailed, comprehensive 3D digital model of the wreck site. Doing so will provide the means to share the submarine's story with current and future generations. It will also deter those who may illicitly seek to be the first to undertake a detailed examination, provide a benchmark by which the site's condition may be monitored, which will assist in its ongoing management. Finally, a detailed 3D survey of the submarine may provide additional clues that could assist in determining what led to its loss. Such an initiative should include the following:

- A work or survey/inspection class remotely-operated vehicle (ROV).
- The opportunity to gather environmental and corrosion potential measurements using this ROV.
- A smaller observation class ROV that is more agile and able to undertake specific examination surveys within the submarine's hull, should such an activity be justified and approved.
- A follow-up examination of the unusual circular hole in Number 6 Main Ballast Tank, and the pressure hull in the vicinity of this hole.
- Appropriate protocols for dissemination and use of footage of human remains should be enacted in the event they are encountered. Footage and still shots of human remains should not be publicly released, unless doing so contributes directly to an understanding of what led to *AE1*'s loss.
- Prompting of relevant stakeholders to develop appropriate legislative protection for the wreck site.
- Given *AE1*'s current condition (e.g., a partially collapsed hull and clear signs of corrosion of the submarine's metal fabric) and the prospect that additional damage is likely to occur as a result of the environment in which the wreck site is located, the follow up archaeological survey should occur as soon as possible.

Immediate steps should be taken to protect the wreck by declaring an exclusion zone around it, further longer-term measures are recommended in Annex F.

The final image is a sonar mosaic developed by Fugro in a post search analysis.

**Figure 29 - Post Search Analysis Sonar Mosaic (Image: Fugro)**



P Briggs AO CSC
RADM RAN Rtd
Chairman of Find *AE1* Ltd and Expedition Team Leader

23November 2018

## Annexes:

A. List of Volunteers and Sponsors.
B. Expedition Team Members.
C. Contact Classification Regime.
D. P Briggs Email 1246K of 20Dec17 – The Men of *AE1* Have Been Found.
E. Find *AE1* Ltd Search for *AE1* December 2017 – What Happened to HMAS *AE1* and Search Image Highlights, Captain Roger Turner CEng FIMarEST RN.
F. Protection of *AE1*.
G. Physical Oceanography of the *AE1* Wreck Site, Dr Ian MacLeod.

## Attachments (Soft Copy only unless indicated)

1. *HMAS AE1* Search History Timeline, hard copy.
2. Registration of Interest Letter dated 19 January 2015.
3. Finding *AE1* Workshop ANMM 06Dec16, hard copy.
4. Finance Agreement - Find *AE1* & Dept of Defence.
5. Grant Agreement between ANMF & Find *AE1*.
6. Decision Brief for Principals 24Nov17, (Fugro Contract included in attachments). Commercial in confidence, hard copy included in ANMM copy of Report only.
7. Decision Brief for Principals 11Dec17.
8. Find *AE1 Letter* To PNG Customs & Immigration Authorities.
9. Find *AE1* Research Proposal to PNG NMAG dated 31Oct17.
10. PNG NMAG Permit dated 11Nov17.
11. Individual Agreement.
12. Descendant Families Letter of Appreciation, Ms Vera Ryan dated 24Dec17, hard copy.
13. *AE1* - Newsletter 11th January 2018, hard copy.
14. Fugro Daily Operations Reports 13-21Dec17.

# HMAS *AE1*

## Annex A – Finding the Men of *AE1* – List of Volunteers & Sponsors

Version 2
November 2018

Find The Men of AE1

# Table of Contents

# 1 Introduction

Since its inception on 20 December 2013 *Find AE1 Ltd* has been fueled by the efforts and in-kind support of volunteers; including descendants of the crew, and associates, some professional others passionate enthusiasts from a variety of backgrounds. Throughout the company's existence the energy and passion of these groups has been outstanding. Funds have always been tight, hard won and greatly appreciated.

# 2 *Find AE1 Ltd* Board

The Board of *Find AE1 Ltd* not only fulfilled its collective statutory responsibilities in the governance and operation of the company, but also as individuals they provided their professional services in kind or *pro bono,* sought donations throughout the community and acted as ambassadors for the cause, "Find the Men of *AE1*". The Board is comprised of:

| | |
|---|---|
| **Rear Admiral Peter Briggs AO CSC RAN Rtd.** | Chairman |
| **Commodore Terence Roach AM RAN Rtd.** | Deputy Chairman |
| **Trevor Lloyd** | Director |
| **Paul Wetherill** | Director |
| **Dr. John White** | Director |
| **Dr. Michael White OAM QC** | Director |
| **Captain Ken Greig OAM RAN Rtd** | Company Secretary |

# 3 *AE1* Descendant Families Association

The crew of HMAS *AE1* were the Fathers, Sons, Brothers and Uncles of 35 families who never forgot them. They have lived with the unbearable pain of the loss of their loved ones being surrounded in unfathomable mystery. Submariners have long understood the importance to "farewell" a family member and as such have a duty to find out what happened to *AE1* in order to provide some comfort to the families.

Descendants formed a group at the time of the research and searches by the late Commander JD Foster OAM RAN Rtd. Later, this group organised under the banner of the *AE1* Descendant Families Association with the triumvirate of Robyn Rosenstrauss, Vera Ryan and Tom Tribe; descendants of Chief ERA Class 1 James Fettes, Chief ERA Class 3 John Messenger and Petty Officer William Tribe respectively, as the association's leadership. Their tireless efforts have been greatly supported by the other descendant families; including both the Wilson and Scarlett families, Chief ERA Class 2 Joseph Wilson and Lieutenant the Honourable Leopold Scarlett respectively, who donated their forbear's decorations to the Australian National Maritime Museum collection.

# 4 Submariners

Sir Winston Churchill, First Lord of the Admiralty in 1914 said *"Of all the branches of men in the forces there is none which shows more devotion and faces grimmer perils than the submariners"*. The care submariners have for one another meant the loss of *AE1* was sorely felt and bestowed an obligation on those who followed to Find the Men of *AE1* and lay them to rest.

The Submarine Institute of Australia (SIA) has been foremost in supporting the most recent activities. The SIA has not only supported *Find AE1 Ltd* with funds, but also in the technical aspects of planning the searches. The SIA President Commodore Mark Sander RAN Rtd, Secretary Commander Frank Owen RAN Rtd and Executive Director Commander David Nichols RAN Rtd are notable for their contribution to the project's success.

The Submarine Association of Australia (SAA) has been a stalwart supporter of *Find AE1 Ltd*. From turning out in force and parading the SAA banners at the unveiling of the *AE1* commemorative plaque at Garden Island, the annual commemorative services held at Gordon by the SAA Motor Cycle Group and at The Shrine by the Victoria Branch, to the plaques in Canberra at the Australian War Memorial (AWM) and in Fremantle at the Western Australian Maritime Museum (WAMM). SAA support has been wholehearted and enduring.

The Submariners Association, in particular the Barrow in Furness Branch has long supported the efforts of *Find AE1 Ltd* with research and detailed information on the boats and their crew. The indomitable Barrie Downer MBE (retired Lieutenant Commander RN) was instrumental in the installation of a commemorative plaque on behalf of *AE1* Inc. and the *AE1* Descendant Families Association at a prominent position in Barrow, close to where *AE1* was built.

# 5 Volunteers/Associates/Workshop Participants

- Dr. Stuart Anstee;
- Dr. Ross Bastiaan AM RFD;
- RADM Peter Briggs AO CSC RAN Rtd;
- Mr. Darren Brown;
- Mr. David Donahue;
- Dr. Nigel Erskine;
- Dr. Neil Gordon;
- CAPT Ken Greig OAM RAN Rtd;
- Mr. Ted Graham AM;
- Mr. Peter Graham;
- Dr. Jeremy Green;
- Dr. Kieran Hosty;
- Mr. Paul Hundley;
- Dr. James Hunter;
- Mr. John Jeremy AM;
- Dr. Elizabeth Johnstone;
- Dr. Ian MacLeod;
- Mr. Gus Mellon;
- Ms. Irini Malliaros;
- Dr. Garth Morgan;
- Mr. John Mullen;
- Dr. Roger Neill;
- CMDR David Nichols RAN Rtd;
- CAPT Ian Noble RAN Rtd;
- CMDR Frank Owen RAN Rtd;
- Mr. John Perryman;
- CDRE Kim Pitt AM RAN Rtd;
- Mr. John Richardson;
- Mr. Peter Richardson;
- Mr. Michael Rikard-Bell;
- CDRE Terence Roach AM RAN Rtd
- Mr. Tim Smith OAM;
- CAPT Roger Turner RN Rtd;
- Dr. Michael White OAM QC; and
- CMDR John Young RAN Rtd.
-

# 6 Find AE1 Sponsors

Throughout the four years of operations *Find AE1 Ltd* has enjoyed the generous sponsorship of:

- Arthur J Gallagher & Co Aus. Ltd;
- ASC Pty Ltd;
- Australian National Maritime Museum;
- CAPT Peter Sinclair AM RAN Rtd;
- Defence Network Services;
- Defence Science and Technology Group; and
- IJS Global;
- IX Blue (formerly IXSurvey Australia);
- Land and Marine Services Pty.;
- Lockheed Martin Australia;
- McTaggart Scott Australia;
- MetOcean Solutions Ltd;
- Mr. Gus Mellon (retired Lieutenant RAN);
- Naval Group (formerly DCNS);
- RSL Queensland Branch;
- RSL Victoria Branch;
- SAAB Technologies;
- Sea and Land Technologies;
- Secora;
- SERCO;
- SONARTECH ATLAS;
- Taylored Offshore Services;
- The Submarine Institute of Australia; and
- ThyssenKrupp;

And most recently major sponsorship enabling the successful search has been received from the:

- Commonwealth Government;
- Fugro NV;
- Royal Australian Navy; and
- Silent World Foundation and sponsors listed below.

Find AE1 wishes to record its appreciation for the sponsors who supported the Australian National Maritime Foundation's contribution towards 50% of the Fugro cost of the search:

News Corp
Commonwealth Bank
Fugro
Goodman Group

John and Jacqueline Mullen
Arthur Tzaneros
Terry Tzaneros
Macquarie Group and Directors
Macquarie Group Foundation
Goldman Sachs Gives on behalf of Christian Johnston
Australian Capital Equity
Navantia Australia
Qantas Airways Limited
Malcolm Broomhead
Peter Dexter AM
Daniel and Helene Janes
Guy and Debbie Templeton
Rob Sindel

Without this generous support the search would not have been possible.

# HMAS *AE1*

## Annex B – Finding the Men of *AE1* – Expedition Team

January 2018

Find The Men of AE1

# Table of Contents

# 1 Finding The Men of *AE1* Expedition Team

| Name | Remarks |
|---|---|
| James McPherson | RAN Liaison Officer, analyst support. |
| Dr. Nigel Erskine | ANMM Observer, maritime archaeologist advice, data manager. |
| Bayden Findlay | Audio Visual (AV) Technician. |
| Irini Malliaros | Maritime archaeologist, Silentworld Foundation representative, AV assistant |
| Paul Hundley | Maritime archaeologist Silentworld Foundation, assistant data manager, analyst support. |
| Roger Turner | Risk management, analyst support and assistant data manager |
| Gus Mellon | PNG & local relations, analyst support, boat transfers |
| Peter Briggs | Client Representative, Expedition Team Leader. |
| *Terence Roach | Deputy Expedition Team Leader, AUS Based Support. |
| *Ken Greig | Project Manager, Logistic Support. |
| *Tim Smith | Maritime Archaeology Adviser |
| *Dr. Ian MacLeod | Corrosion & Conservation Scientific Adviser |
| *Dr. Roger Neill | Science & Technology Adviser |

Note: * indicates Australia based – not embarked in *MV Fugro Equator*

# HMAS *AE1*

## Annex C – Finding the Men of the *AE1* – Contact Classification

January 2018

Find The Men of AE1

# Table of Contents

# 1 Contact Categorisation

## 1.1 Class 1

Interesting, isolated natural origin like a rock outcrop, landslide etc.

## 1.2 Class 2

Interesting, isolated and based on shape probably of man-made origin like a container, an oil drum, some loose metal but smaller in size than expected target.

## 1.3 Class 3

An area of not natural debris matching size of search target, definitely man-made features or signs of clear wreckage.

# 2 Contract Categorisation – Category 3

## 2.1 Class 3A (POSS-*AE1*)

Contact held on one type of sensor exhibiting the characteristics of *AE1* (size, shape, or portion thereof).

## 2.2 Class 3B (PROB-*AE1*)

Contact held on two, independent sensors exhibiting the characteristics of *AE1* (size, shape, or portion thereof).

## 2.3 Class 3C (CERT-*AE1*)

Visual confirmation in addition to another sensor.

# 3 Contact Serial Numbers

- Individual team member's contact
  - Into a shared Excel file, coordinated by Magnus.
  - Searcher ID column x Mission Number row.
  - Enter ping number of Y if clear of contacts

- Master Contact assessment of individual's contacts assessed by Candran, Magnus and Peter leading to:
  - FE (*Fugro Equator*) nnn.
  - Classification level 1,2,3A, 3B or 3C.

- Existing contacts:
  - DS 1-23 (*Deepstar*)
  - Y1 (*Yarra*)

# HMAS *AE1*

## Annex D – Finding the Men of the *AE1* – Email 20/12/17

January 2018

Find The Men of AE1

# Table of Contents

# 1 Email from Peter Briggs – 20 December 2017

**From:** Peter Briggs [mailto:peterbriggs1955@me.com]
**Sent:** Wednesday, 20 December 2017 1:47 PM
**To:** Barrett, Timothy VADM; DR Kevin Sumption PSM; John Mullen; Paul Kennedy
**Cc:** van Stralen, Letitia CAPT - RAN; Terence Roach; Ken Greig; Elliott, Pup MR; Paul Seaton; Barry Clifford
**Subject:** The Men of AE1 Have Been Found

**IN CONFIDENCE**

Gentlemen,
I am delighted to advise that the men of AE1 have been found.

Analysis of the first line of the AUV Mission 01 following recovery pm Tuesday, 19Dec17 located a contact, identified as FE-04, matching AE1's dimensions lying off the Duke of York islands in over 300m of water in area A on a heading of 236 (consistent with the course for return to Rabaul).

- The contact is also present on the ship's MBES.
- Follow up analysis of Mission 01 AUV SSS revealed that FE-04 appeared to have forward and after hydroplanes.

AUV Mission 02 was used to obtain greater detail using the AUV's SSS/MBES on a series of close passes from different aspects and a lower altitude.

This confirmed the hydroplanes but added little detail to the first run.

Great ship handling and survey crew work facilitated extensive drop camera imagery to be taken moving from bow to stern on there starboard side and then moving back up the port side, final series taken of the top of the fin.

There is no doubt that contact FE-04 is AE1.

Intend:

- A short commemorative service near the site.
- Concluding the search and making arrangements to present the education and sports packages to the Mioko Islanders Thu 21Dec,
- Fly the Expedition Team out via Kokopo on 22Dec17 for RTA.

My thanks to you all for your support, to the Ship's crew and the skilled survey party, all of whom have combined to make this possible.

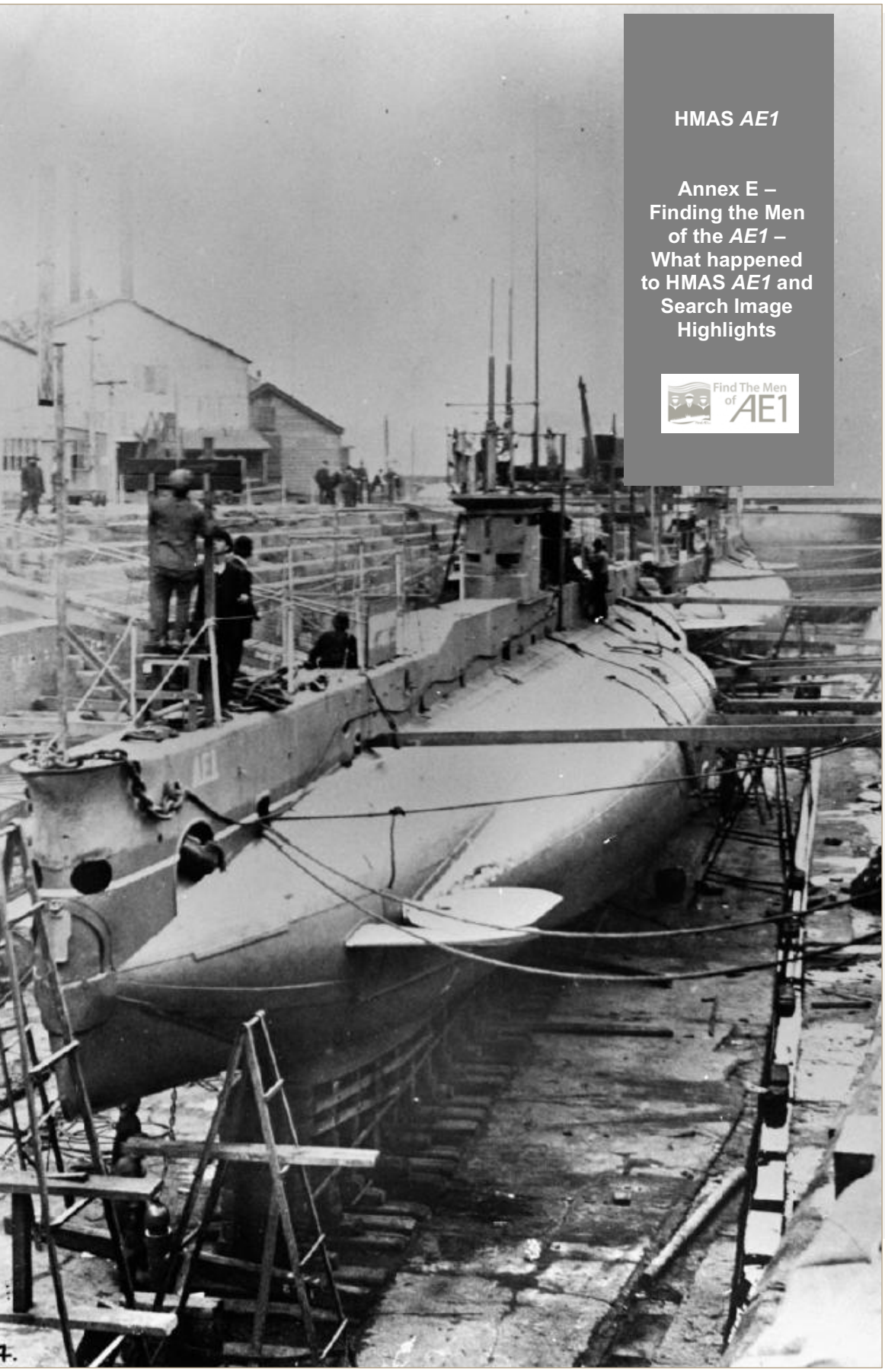
Regards,

Peter Briggs AO CSC
RADM RAN Rtd
Chairman Find AE1 Ltd
ABN 331 673 313 39
peterbriggs1955@mac.com
0401 004 688

www.findae1.org.au

<image001.png>

**IN CONFIDENCE**



HMAS *AE1*

# Annex E – Finding the Men of the *AE1* – What happened to HMAS *AE1* and Search Image Highlights

# Find *AE1* - Search for *AE1* December 2017
# What Happened to HMAS *AE1* and Search Image Highlights

Captain Roger Turner
CEng FIMarEST RN

## Table of Contents



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## List of Figures



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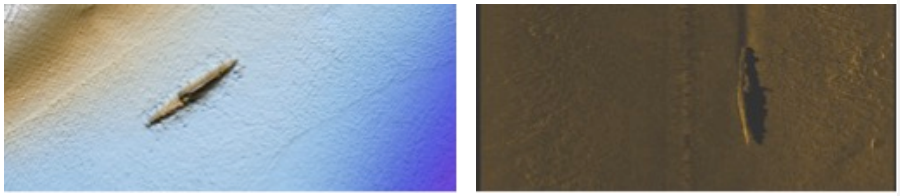
**Figure 1 - Ship MBES and AUV SSS Images**



# 1 Aim

On 14 September 1914, HMAS *AE1* was on picket duty in the St George's Channel to the east of The Duke of York Islands. Although her crew had been operating together for over a year, their opportunities to practise dived operations (ballasting, trimming, depth-keeping, etc) had been limited. She was also suffering a mechanical defect to her starboard main engine clutch, which limited the power available to her when dived. This paper will endeavour to demonstrate that this combination of circumstance would alone have been sufficient to lead to her loss.

# 2 Background Situation

Joining up with her escorting vessel, HMAS *Parramatta*, off Herbertshoe (now Kokopo), *AE1* arrived at her patrol area. *Parramatta* extended her picket line to the south and southeast while *AE1* proceeded northeast. It is possible that the opportunity was taken for the submarine then to conduct a trim dive in order to prove correct ballasting and effective functionality of the systems. This would have been a chance for the crew to practise diving the submarine, the opportunities for which had been scant in the time, which had elapsed since they had taken delivery of the vessel.

The *Find AE1* team believe that the vessels had agreed to rendezvous later and at 1430, *Parramatta* signalled that she "was close to the submarine" in position two miles east of the Duke of York Islands. From there *Parramatta* opened out to the east-southeast.

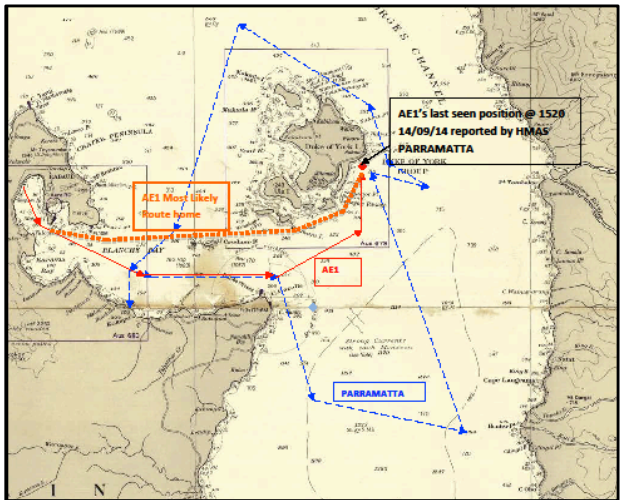
*AE1* then made a signal asking *Parramatta* "What is the distance of visibility?" *Parramatta* replied "About 5 miles". *Parramatta* then records that at 1520 – "submarine was lost sight of". She steamed in close to the coast but saw no trace of *AE1*. More details of this are given in the Search Report[1].

As an aside it is worth considering how these signals were exchanged. In the formal reports there is something of an assumption that the exchange was by WT. However, the images of the wreck show no sign of any WT antennas. Indeed, the WT stump has nothing attached to it, which could be considered an antenna. This would suggest that in being cleared for diving the submarine had stowed the WT antenna and that the signal exchange with *Parramatta* was made by light or megaphone.

Dubbed the Last Known Position [LKP] this approximate position of the submarine at around 1430 formed an important datum in establishing the search areas. Combined with a careful consideration of other factors, the search areas were defined to cover, with due margins for error, the LKP and the return from there to Rabaul on an assumption that, dived or surfaced, *AE1* would have been anxious to head for harbour and meet the direct order to "be home by dark" that had been given to him that morning. This assumption proved correct in that the wreck has now been found on the most direct line to Rabaul. The wreck is aligned on a heading, which would be taking it towards Rabaul.

[1] AE1 Search Report 2012-13 dated 10 Feb 2012

**Figure 2 - Track Chart of HMAS *Parramatta* and HMAS *AE1* on 14 September 1914**




## 3 E-Class Characteristics

The E-Class operating depth was 30.5m (100ft), which was extended to 61m (200ft) on outbreak of hostilities. The build specification for the submarines requires the depth dependent systems to be tested to 100psi (61m depth), which is unusual by today's standards and does not allow any margin beyond the operating depth. An exception to this was the bilge pump, which was tested to 200psi. This would, theoretically, allow it to operate down to 120m. The high-pressure air and ballast blowing system operated at 2,500psi and the system was designed to achieve a pressure of not less than 5psi above the external pressure when all the tanks were being blown at once.

There are cases recorded of submarines having gone deeper than 61m (200ft). Notably, after a trimming accident the similarly constructed HMS H-8 bottomed at 72m (235ft). It appears she had difficulty blowing main ballast at that depth but successfully pumped out ballast to achieve positive buoyancy and successfully returned to the surface.

The E-Class had a riveted hull construction, which makes it hard to estimate what the crush depth would be. A conservative band of expectation would be that the hull would begin to fail below 90-120 metres (300-400ft).

**Figure 3 - Tile Cam of AUV images**

# 4 Evidence Gathered from the Search Imagery

Examination of the wreck imagery reveals the following points:

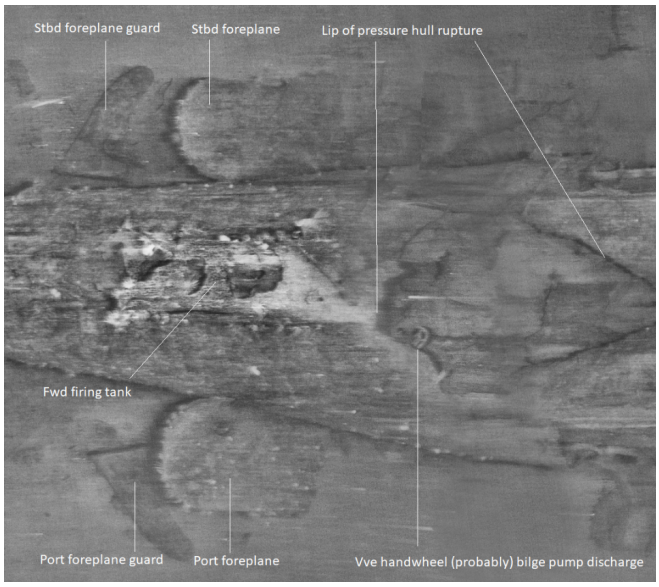
- The wreck is lying upright on a level sea bed at a depth of over 300m.
- Ship's head is at 235°T – on course consistent with her return to Rabaul.
- The fin guardrails and stanchions are stowed – she was rigged for diving.
- The upper conning tower hatch appears to be shut – rigged for diving or being dived.
- The bridge wheel (which can be removed to the conning tower) is in place – suggesting that they were not expecting to be dived for long or that removal had not yet become operational practice.
- Both forward and after hydroplanes are set hard to rise - the submarine had forward way and was endeavouring to return to the surface.
- The bow casing is dislodged and there is much damage to the ballast tanks – the consequence of a heavy impact and of subsequent erosion/corrosion.
- The forward torpedo tube (bow) cap appears in shape – the impact was with the underside of the tube, pressure hull or keel implying an impact angle of up to 20° (keel only) or as much as 30° (keel and pressure hull).
- All four hydroplane guards have sheared off and are lying on the sea bed at different angles and in different positions near to below their original positions.
- There is extensive damage to the pressure hull from the area of the fin forward between frames 56 and 84 – the consequence of a catastrophic collapse or implosion.
- An area of the pressure hull within the collapse appears less damaged in way of the bulkhead between the control room and forward torpedo compartment at frame 76.
- A valve handwheel (probably the bilge pump discharge valve) can be seen aft of the forward torpedo tube firing tank and below a lip in the imploded pressure hull. The E-Class had no handwheels fitted outside the pressure hull – hence this is clear evidence that the pressure hull is ruptured.
- There is further pressure hull damage beneath the fin.
- The fin itself has toppled forward probably into the collapsed control room pressure hull.
- The fin has also hinged forward about its forward edge separating the upper conning tower from the lower conning tower along its riveted flanged joint – possibly the result of the implosion and/or the consequence of having struck the bottom at some speed and at a steep bow-down angle.
- Both periscopes are in the raised position although the after periscope appears shorter than it should be – probably the consequence of the fin having tilted forward.
- The after sections of the fin plating are missing.
- A rectangular section of plating is lying on the seabed abreast the fin to starboard of its forward edge.
- The WT antenna stump is intact with no antenna wire visible.
- There are no signs of a WT mast.
- The after beam-torpedo tube firing tank has (apparently) collapsed while the forward beam-torpedo tube firing tank has not – suggests one had flooded and equalised while the other had not which may have contributed to a trim/ballasting imbalance.
- There are three (or more) high-copper-content pipework flanges or gaskets lying in different locations on the pressure hull. Their hole configuration suggests they are High Pressure (HP) air system related. The advancement of their corrosion suggests that the HP air burst, which left them where they are, may have taken place some time after the sinking event.
- The pressure hull aft of the fin is (apparently) intact.
- The Engine Room (ER) hatch and casing cover are missing – probably blown off by an internal pressure wave resulting from the flood.
- One (the furthest aft of three) ER hatch strong back(s) is (apparently) still in place in the ER hatch opening.
- The exhaust tank discharge pipework is in place (though damaged) while the exhaust overboard discharge pipework is missing.
- There is little sedimentation visible on the sea bed – implies that there was nothing to soften the impact of the grounding.
- There are many areas of damage/collapse to the saddle tanks – probably the consequence of a second vertical impact.

**Commented [DJK1]:** Suggest deleting – stick with the facts.

- There are many areas of corrosion, for example, the forward edges of the after planes. As the area is subject to seasonal currents of up to 3 knots and current-borne sedimentation is of volcanic sand the erosion/corrosion mechanisms are likely to be severe.

Those points are illustrated by the following images:

**Figure 4 – Forward Hydroplanes & Hydroplane Guards + Handwheel (probably Bilge Pump Outlet vve)**




## 4.1 Notes – Figure 4

- Port and starboard forward hydroplanes with sheared-off plane guards lying on seabed.
- Forward hydroplanes are set to rise.
- The pale item on the casing is what remains of the badly corroded fwd firing tank.
- A shadowed lip edge of the crushed pressure hull.
- Valve handwheel, probably the bilge pump outlet. E-class had no handwheels outside of the pressure hull hence this is clear evidence that the pressure hull has been crushed.
- Debris lying aft of the handwheel is probably the remains of the casing and pressure hull.

**Figure 5 - Handwheel & Forward Torpedo Tube Firing Tank (Bow is to the right)**

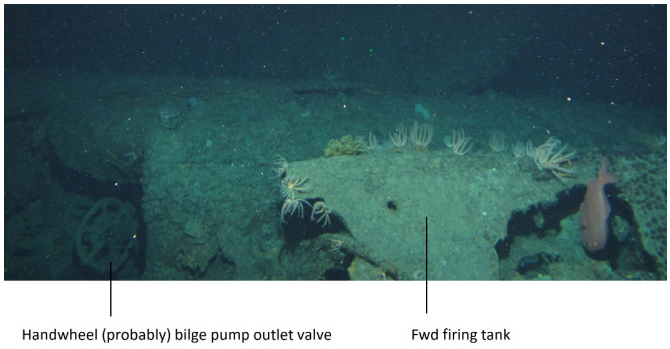


**Figure 6 - Fin Area (A)**

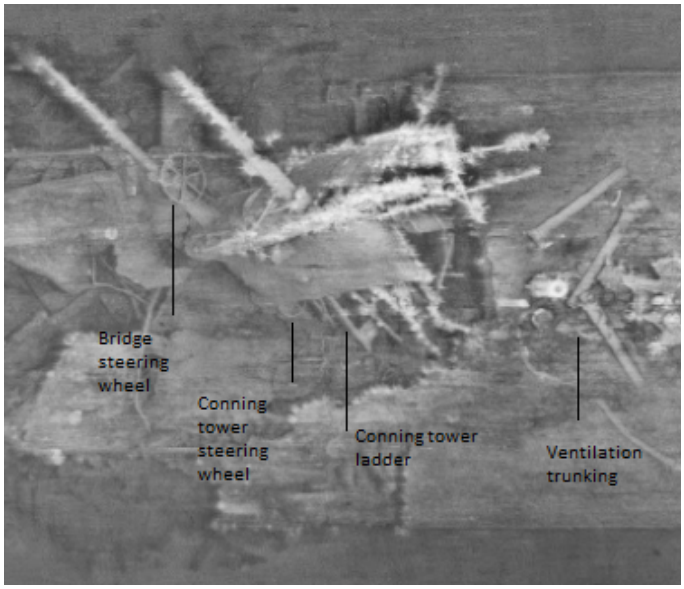



**Figure 7 - Fin Area (B)**

WT antenna stump

Possible section of fin plating

Guardrail stanchions folded flat

Conning tower upper hatch and operating shaft.

**Figure 8 - Fin Area (C)**


Notes – Figures 6, 7 & 8

- Conning tower upper hatch shut.
- Bridge wheel is in place (not stowed in conning tower).
- WT antenna stump is intact (appears foreshortened by camera angle).
- Guardrail stanchions folded flat for diving.
- Forward periscope is fully raised.
- After periscope appears raised but is not in a fully raised position – probably the consequence of the lifted fin.

**Figure 9 - Fin Area (D)**


## 4.2 Notes – Figure 9

- Missing sections of after fin plating port and starboard sides.

**Figure 10 - Ventilation System Pipework**

## 4.3 Notes – Figure 10

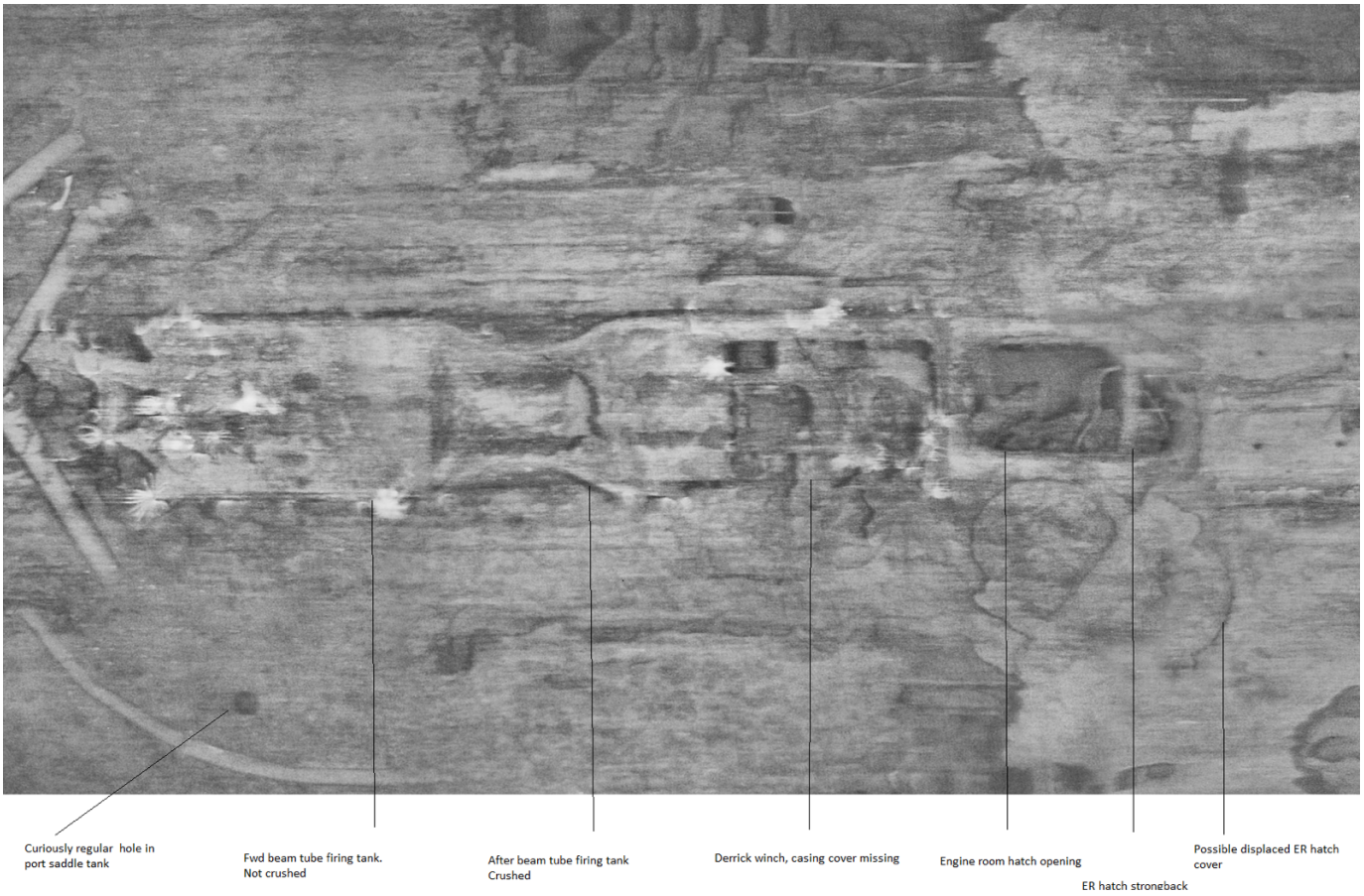
- Shows three (of five) ventilation trunks.
- Trunks have been exposed (and dislodged) by lifting of the fin.
- The two (dull) circular shapes are ventilation sluice valve flanges.
- The (brighter) flange has (probably) been exposed following one trunk being wrenched off its sluice valve connection.

**Figure 11 - Casing & Riveted Pressure Hull damage to Port and forward of the Fin**

## 4.4 Notes – Figure 11

- Shows rupture of riveted pressure hull plating and small-bore pipework
- Bright (blue) coloured 6-holed flange or gasket– probably of (high copper content) gunmetal or copper
- The configuration of the flange suggests it is probably high-pressure air system related either a system flange or gasket.
- Comment: That the disc has corroded thus suggests that up to 25 years of pressure hull corrosion may have taken place before the event occurred which deposited the disc where it now is.
- Two similar discs are also visible (Fig 6) located on the port and starboard saddle tanks.
- The regular shape (bottom left) is the port forward fin edge.

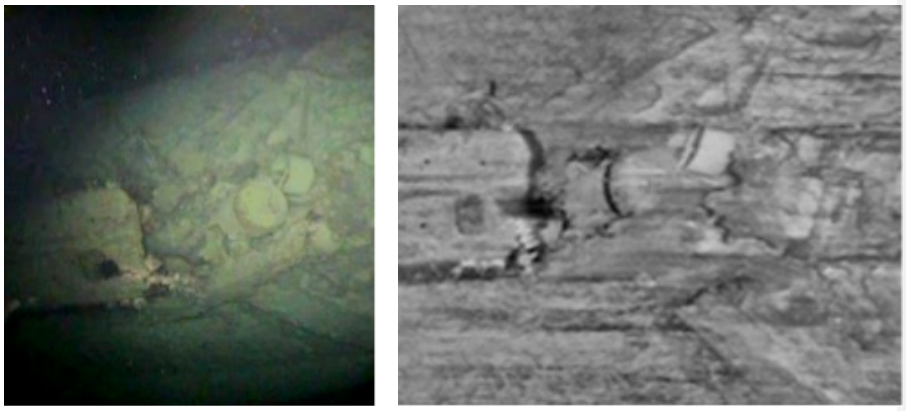
**Figure 12 - Beam Torpedo Tube Firing Tanks & Engine Room Hatch Area**



## 4.5 Notes – Figure 12

- Forward (port firing) beam torpedo tube firing tank is largely intact.
- After (starboard firing) beam torpedo tube firing tank has been crushed – implies that the pressure equalised in one and not the other – they may have been configured differently.

**Figure 13 - Exhaust Tank Outlet Pipework**



## 4.6 Notes – Figure 13

- Exhaust tank outlet pipework debris remains while the overboard sections are missing.

**Figure 14 - Stern Section**

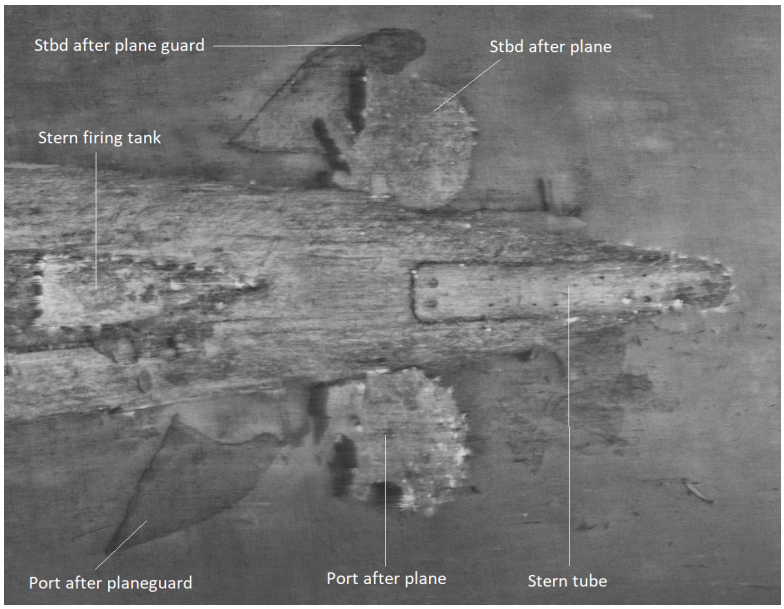


**Figure 15 - Stern Firing Tank & Port After Hydroplane**

## 4.7 Notes – Figures 14 & 15

- Different angles and positions of after hydroplane guards relative to their original positions.
- Effects of erosion/corrosion on the forward edges of the after planes.

**Figure 16 - Stern Tube, Port After Hydroplane & Propeller**

**Figure 17 - Nos 6 & 8 Main Ballast Tanks**

### 4.8 Notes – Figure 16

- Comparatively little deterioration of these Main Ballast Tanks compared with all others.

## 5 Deductions & Sequence of Events

The record of events leading up to the loss of the submarine and the condition of the wreck as described (except where already caveated) constitute the facts as we know them to be. From these alone it is impossible to draw any exact conclusions as to what happened in between AE1's leaving the LKP and settling where she now lies. However, from the accumulation of evidence it is possible to make some deductions. To do so does inevitably require a degree of speculation the application of which is indicated by appropriate use of the words possible or probable.

- The submarine was in the dived condition being either diving or dived.
- At some point, the submarine lost trim and or control, became heavy forward and assumed a bow down angle. There are a number of ways in which this could happen: the consequence of a design failure, material failure, operator error or combinations thereof.
- With way ahead on the submarine, the planes were set to rise in an attempt to regain a bow up angle. This would have to have been a deliberate action. Operated by a rack and pinion mechanism and designed to operate against maximum design speed, the planes could not have drifted into their current positions.
- The single operating shaft (port) (if applied) was insufficient when going astern to arrest the dive.
- Attempts at blowing ballast (if made) were ineffective (incorrect order given, order not correctly carried out, main vent left open, too deep for blow to be effective, etc).
- As the submarine went deeper it would have been compressed making it relatively heavier and thus less likely to recover.
- At a depth of >100m the external pressure exceeded hull strength and the forward section in the region of the control room imploded - possibly initiated around the forward fin or forward torpedo loading hatch area.

- The shock wave generated by the implosion passed aft through to the after section thus equalising its pressure and saving it from implosion.
- The shock wave resulted in an explosive pressure, which dislodged the Engine Room hatch.
- The flood caused the submarine to become still heavier with an increasing bow down angle.
- At an increasing speed of (assumed) 10 knots and an angle of up to 30° the submarine would have struck the bottom after a further 40-50 seconds.
- At that angle (or less) the point of impact would be the underside of the pressure hull bow section.
- If this had not already occurred as a consequence of the implosion, a cantilever effect of momentum and angle caused the fin to topple into the collapsed control room.
- Continued momentum by the fin and conning tower caused the CT Upper Section to hinge forward shearing off at the join with the lower section.
- Plating on the after section of the fin was torn away from both fin and casing.
- Momentum (and height above sea bed) caused that plating to be thrown forward.
- This primary impact would result in a severe whiplash or flexing effect, which could cause much of the other damage now visible.
- The hull then fell back leading to a second impact as it landed flat on the keel (probably the after section).
- This caused a second round of "pancake" damage with (possibly) further recoil and bounce damage. This probably caused (for example) the plane guard damage and damage to the ballast tanks.
- It is possible that the planeguards all fell some time later as a consequence of their fixings having corroded though it is unlikely that this would have occurred without the guards themselves also corroding.
- Exposure of the ruptured metal to the erosive effect of current-borne (largely "sharp" volcanic) sedimentary sands now prevents the build-up of concretion, which can protect such metal from corrosion. This effect is reduced with distance from the sea bed hence (for example) the leading edges of the after planes show greater deterioration than the fin.
- Deterioration of the wreck through erosion/corrosion is very evident, particularly at the lower levels although there are some curious exceptions such as in the area of the No's 6 and 8 Main Ballast Tanks.
- It is possible that further damage occurred up to 25 years later as a consequence of more than one HP Air system failure.

**Figure 18 After hydroplanes and rudder operating mechanism (Courtesy Dr Roger Neill)**

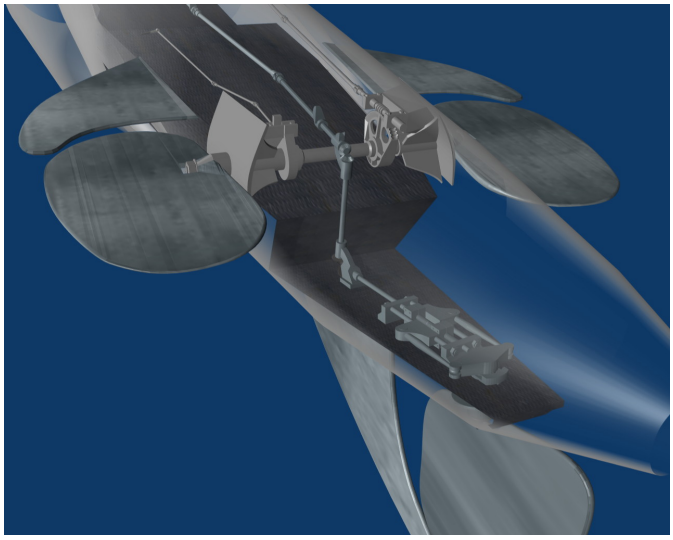
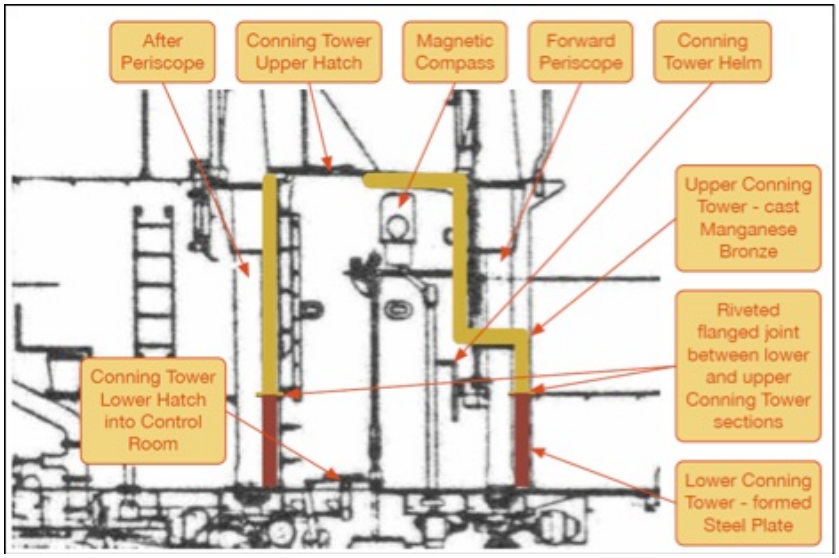


**Figure 19 - Extract of Plans to illustrate Fin Failure Mode**




## 6 Defining the Cause of the Accident

The Search Report speculates that there are eight options for how *AE1* could have been lost. In light of what is now known of the position and condition of the wreck, we can revisit those options, recognising that in doing so we are again speculating beyond the exactitude of the evidence. The options are placed in the order that they appear in Table 1 of the Search Report:

1. A bow-on grounding – given that the wreck lies more than a mile from shallow water, this can be discounted.
2. An internal explosion – this was assessed as being an unlikely cause of the loss and there is no evidence to suggest that assessment should be amended.
3. Grounding whilst dived – given that the wreck lies at a depth of > 300m, this option can be discounted.
4. Run down by Parramatta whilst dived – Parramatta's track chart shows her as being around five miles from the position of the wreck, which allows this option to be discounted.
5. Combined scenario – grounding, dived to correct list, run down en-route to harbour. Again, given the distance from shallow water and a vessel with which to collide, this option can be discounted.
6. Sunk in engagement with enemy – the possibility that the armed German river vessel Kolonial Gesellschaft [KG] could have ventured out of Mioko Harbour and intercepted the returning *AE1* was assessed as being possible but not probable. While the position of the wreck could, perhaps be considered consistent with this theory, it is unlikely that an action at that location could have gone unobserved or unheard by Parramatta. Furthermore, the light armament of KG was such that they would, most probably target the fin of the submarine, which shows no damage consistent with such an attack. On balance the new evidence suggests this option remains possible but still less probable.
7. Navigational Accident - the distance of the wreck from shallow water can allow the several options for grounding accidents to be ruled out.
8. A diving accident - *AE1* left the LKP heading for Rabaul. Clearing Mioko Island (some 20 minutes later) she found she had time in hand and made a practice dive. She failed to catch a good trim on diving, for which there could be a number of explanations, and, with only one shaft available to arrest the dive she then carried on down.

Option 8 raises a question in that if *AE1* left the LKP for Rabaul promptly enough to leave time for a practice dive, how could Parramatta not have seen her go? The answer could be as simple as poor look-out astern in gathering haze made worse by Parramatta's own smoke. This was such that the submarine's departure was not immediately noticed and that by the time the lookouts were re-alerted, the two vessels had already opened out by more than the five miles' visibility. This, we can infer, was the conclusion reached by Parramatta's CO at the time.

The reality is that the records of the day, particularly Parramatta's logs do not give sufficient detail to be more precise about the relative movements of the two vessels and nor need they be for us to conclude that Option 8, an accident on diving is the most probable cause of HMAS *AE1*'s loss.

# 7 Conclusion

The condition of the wreck of HMAS *AE1* and the observations made in the December 2017 search allow deductions to be made from which it is possible to conclude that the submarine foundered as the consequence of a loss of trim and or control whilst diving or dived and that any remedial action then taken was inadequate possibly being aggravated by there being only one propeller shaft available when they were dived.

The sequence of events as speculated can be represented as follows:

**Figure 20 - *AE1* Diving or Dived at or near Periscope Depth suffers an Accident resulting in her losing Trim (Assumes a Bow Down Angle)**

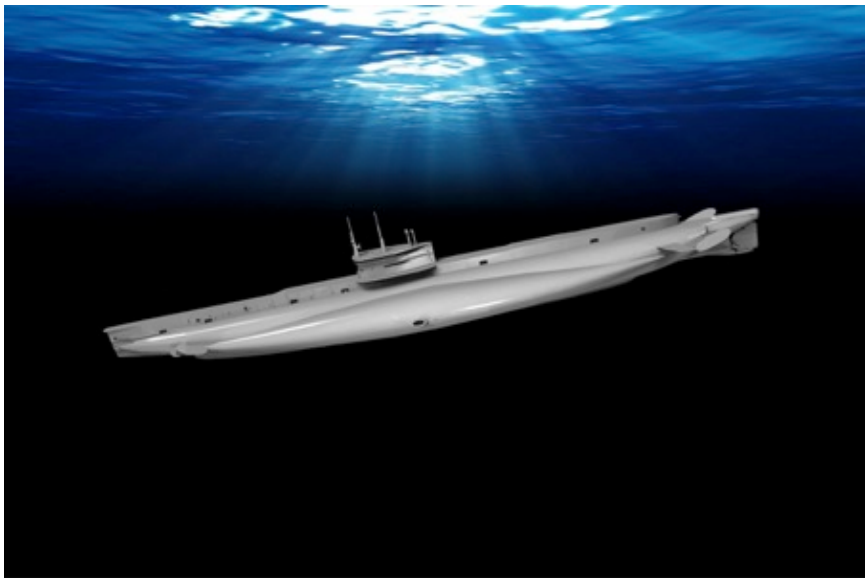


**Figure 21 - Unable to Recover, she carries on down until reaching Crush Depth when the Control Room and Forward Area Implodes. The Shock Wave Blows off the Engine Room Hatch**

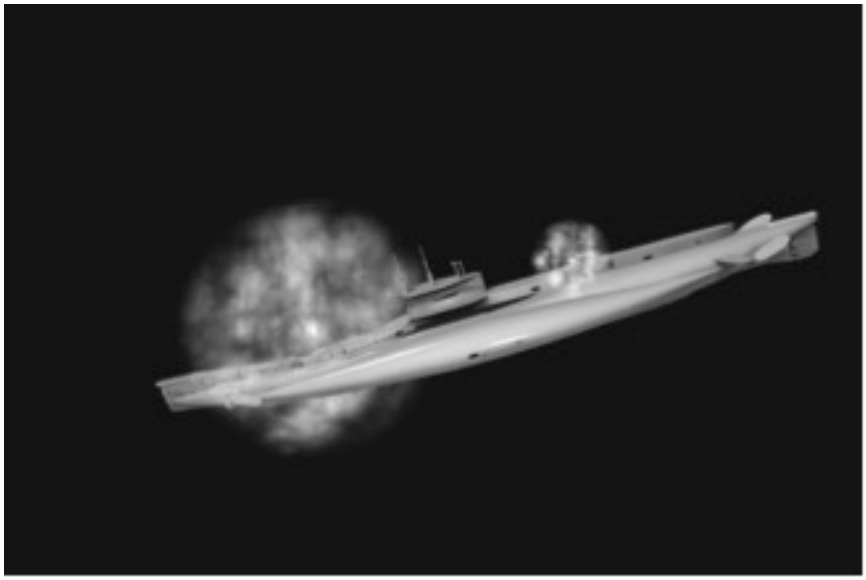


**Figure 22 - *AE1* continues down, gathering speed until she strikes bottom at an angle of up to 30 degrees**

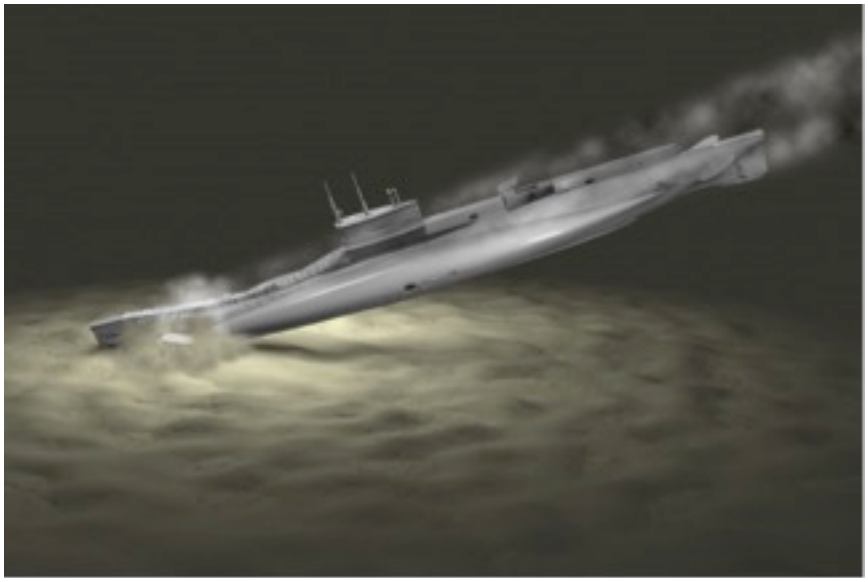


**Figure 23 - Momentum causes the Fin to topple into the imploded Control Room and then for the Upper Conning Tower to hinge forward on its forward edge separating its flanged joint with the Lower Conning Tower**

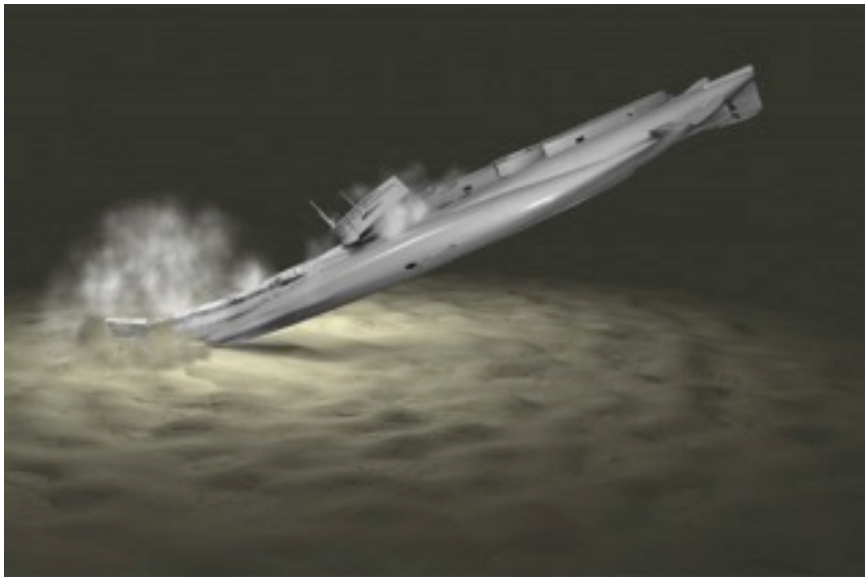
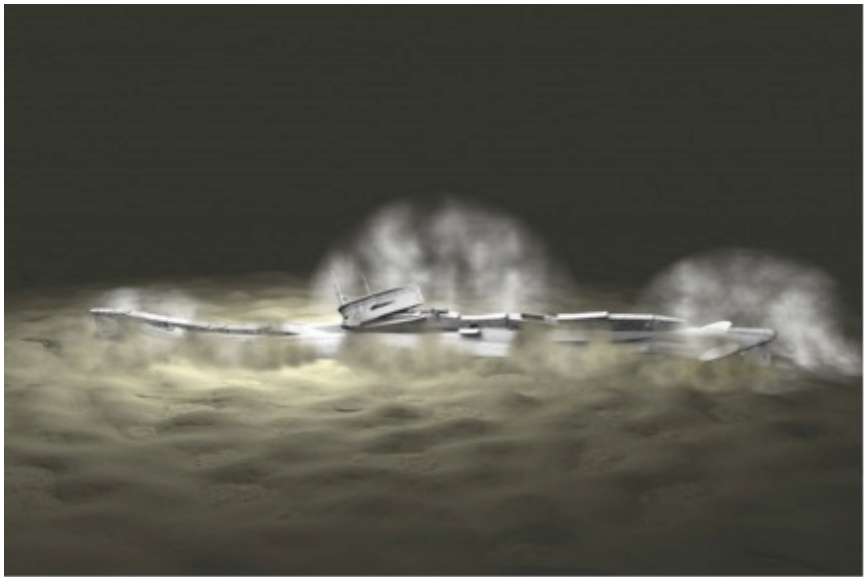
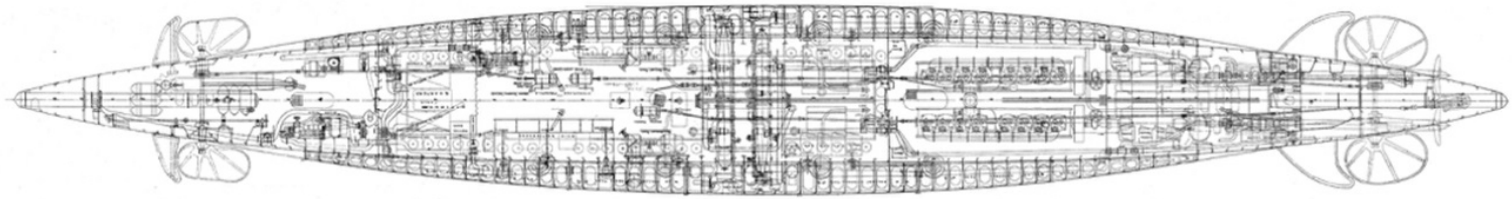
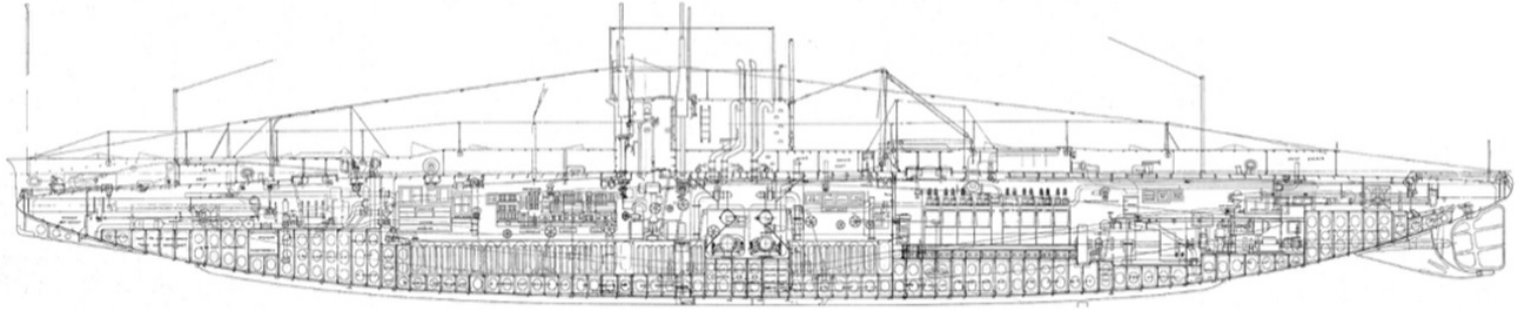


**Figure 24 - The Hull falls back onto its Keel resulting in a second wave of damage, including dislodgement of the Hydroplane Guards**







# HMAS *AE1*

## Annex F – Finding the Men of the *AE1* – Protection of *AE1*

January 2018

Find The Men of AE1

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# 1 Protection of HMAS *AE1*

Find *AE1* Ltd and the Expedition Team advocate a number of long term changes:

- Amend existing PNG NMAG Legislation; expanding its coverage to include World War I relics and shipwrecks from both World Wars.[1]
- Amend the War Graves Act to recognise and protect Maritime sites of National Significance, i.e. wrecks representing the last resting place of Australian servicemen.
- Australia and PNG should ratify the UNESCO Convention for the management of Shipwrecks to provide a common policy basis for future management

Find *AE1* Ltd and the Expedition Team advocate the following short-term measures. These should be put in place as soon as possible. Following the location of the wreck, the clock is now running, for the fame seekers and treasure hunters who will attempt to exploit the wreck or achieve notoriety by obtaining world first images etc:

- A joint Australian/PNG Government declaration should be issued, advising that the site is protected and declaring that:
  - Ships may not anchor, or moor or trawl in the defined area.
  - Recovery of artefacts or material from the wreck is forbidden without a permit.
  - Ships may not examine the wreck, including using ROV or submersibles, or photograph it without a permit.
  - Permits to be issued by the NMAG, with the joint agreement of the PNG and Australian Government.
  - NMAG and ANMM nominated as the managing authorities for their respective Governments, to act collaboratively and in the interest of protecting the site from intrusion or damage.

- Installation of a surveillance camera on Mioko Island, with feed to the NMAG and ANMM (similar to that already installed over the wreck of the *USS Houston* in Indonesia).
  - Annual maintenance visit by NMAG official to Mioko Island to maintain camera and sustain a relationship with the Mioko Islanders.
  - Camera installation, maintenance and annual visit cost funded by the ANMM (paid on receipt of NMAG written Report of visit).
  - Mioko Islanders requested to report any vessel intrusions to NMAG official by mobile phone call.
    - Annual donation of educational material in return, delivered by NMAG officials during visit, funded by ANMM.

[1] *War Surplus Materials Act* 1952 that covers WWII items found on land or in territorial waters of PNG. Under the legislation human remains are also classified as surplus materials, + plus legislative review of the *National Cultural Property Preservation Act 1965*. to see if its scope could be expanded to included underwater cultural heritage. Both Acts are administered by the National Museum.

# HMAS *AE1*

## Annex G – Finding the Men of the *AE1* – Physical Oceanography of the *AE1* Wreck Site

January 2018

Find The Men of AE1

# Physical Oceanography of the *AE1* Wreck Site

Dr Ian D MacLeod
Heritage Conservation Solutions

Draft 1.1, January 23, 2018

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## Executive Summary

The physical oceanography of the wreck site was recorded by *Fugro Equator* on 18 December 2017 at depths up to 1,500 metres. The profiles of both temperature and salinity are complex but the variables were linearised against water depth so that reasonable estimates of the microenvironment conditions of the HMAS *AE1* site can be interpolated.

In the first 160 metres the salinity increases due to the diminishing influence of fresh water coming from the outflow of rivers and streams entering the surface waters. After the impact of fresh water has been overcome through dilution, the salinity decreases logarithmically with increasing water depth until it reaches a plateau level at approximately 500 metres. Plots of the log of salinity versus depth enable the salinity present at the *AE1* site to be estimated at 35.0 ± 0.8 ‰.

The temperature versus depth profile shows a linear decrease of the log of the temperature with increasing depth which gives a calculated wreck site value of 11.6 ºC. When combined with the calculated salinity value the maximum dissolved oxygen content on the wreck, which is interdependent on temperature and salinity, is 8.8 parts per million. This high dissolved oxygen concentration when combined with an average current of up to 3 knots means that the wreck is likely to have suffered significantly more corrosion than her sister ship *AE2*.

Development of an appropriate custom-made heritage conservation solution for the management of this historic shipwreck is an urgent priority for those bodies concerned with the management of such underwater cultural heritage resources.

# 1 Introduction

*Fugro Equator* assessed the physical oceanography of the area on the 18th December 2017 at the conditions located offshore Papua New Guinea, under job number GP 1587. The latitude was 004° 10' 04.59" S and the longitude was 152° 32' 18.69" E. The data was recorded at 19:51 hours using the Midas SVX2 probes with Serial numbers 27530 and 27962. The seawater pH was 7.50 and the data relating to salinity, temperature were recorded up to depths of 1538 metres. The pH of the seawater was low due to the dilution impact of fresh water with the open ocean waters. This is reflected in the fall of alkalinity from a pH of 8.1 ±0.1 for normal seawater makes the surface waters six times more acidic than typical values of seawater at 36 parts per thousand (‰). For the purposes of this report statistical analysis has been conducted on data to the first 1,000 metres since a review of the data from 1,000-1,500 metres showed that it is typical of deep ocean equatorial waters that are at a steady salinity and thermal regime.

# 2 Temperature

A representation of the logarithmic fall in temperatures is seen in Figure 1, where the surface temperatures are essentially constant for the first 60 metres and then the temperature begins to fall in a logarithmic fashion to 470 metres, but from that point there is a slowing down of the rate at which the temperature falls, by a factor of three times (see Table 1).

**Table 1 - Linear Regression Analyses on Salinity to 160m and Log Temperature Profiles at Depth**

| | 27530 linear slope | 27962 linear slope | 27530 Intercept | 27962 Intercept | 27530 $R^2$ | 27962 $R^2$ |
|---|---|---|---|---|---|---|
| salinity 0- 160 m | 0.0149 ± 0.0018 | 0.0129 ±0.0013 | 33.85 ± 0.17 | 33.79 ±0.13 | 0.9274 | 0.9239 |
| log °C 0- 470 m | -0.00154 ± 0.00004 | -0.0015 ± | 1.5913 | 1.5892 | 0.9867 | 0.9910 |
| Slog °C 0-470 – 1,000 m | - 0.0005 | -0.0005 ± | 1.1090 | 1.1179 | 0.9899 | 0.992 |

At a mean depth of 350 metres for the wreck of *AE1* the temperature can be calculated according to the equation

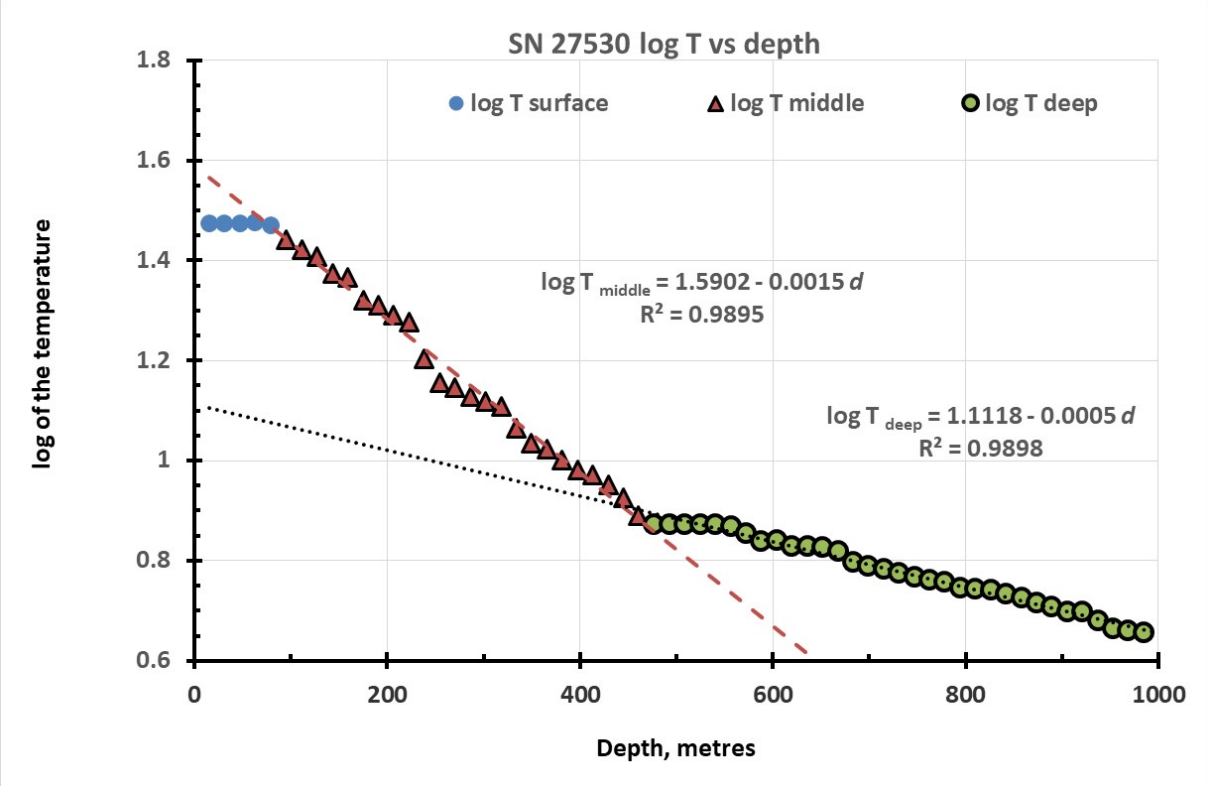
$$\log T_{350\ \text{metres}} = (1.5902-0.0015*350) \qquad (1)$$

The calculated temperature from unit 27530 is 11.62°C. The data collected by unit no 27962 gives a similar set of temperature depth profiles and for this sensor the estimated temperature on the wreck site was 11.59 °C, owing to a slightly different linear regression equation shown as equation 2

$$\log T_{350\ \text{metres}} = (1.5892-0.0015*350) \qquad (2)$$

Since the mean temperature of *AE1* is going to vary over time, because of seasonal variations, the present data provides a good indication what the actual temperature on the site is likely to be i.e. around 11.6 °C.

**Figure 1 - Typical Plot of the Temperature Profiles with Depth in the Waters adjacent to the *AE1* Wreck**

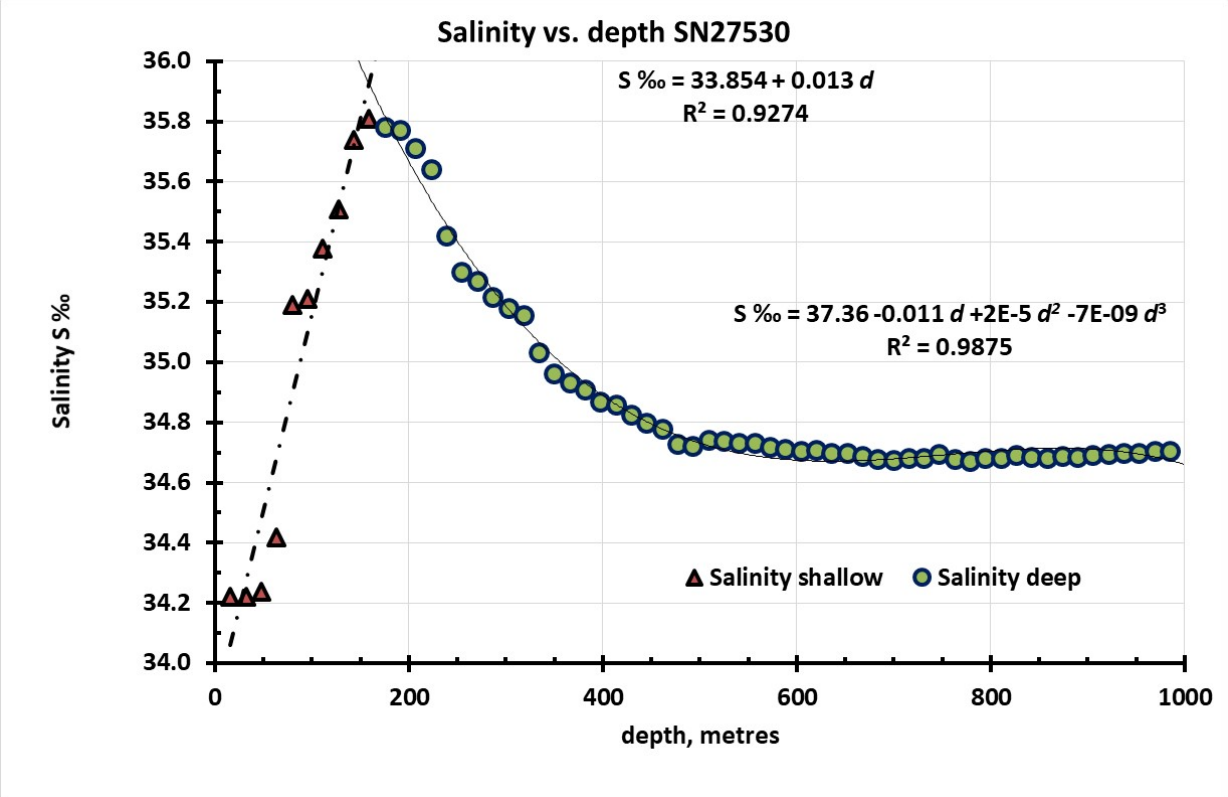



## 3 Salinity

The salinity profiles showed more complex behaviour in that both sensors showed a linear increase in salinity for the first 160 metres and from that point onwards, the salinity regularly fell with increasing depth, as shown in Figure 2. The data from the regression analyses (Table 1) showed that the period of increasing salinity with depth varied from +0.0149 ± 0.0018 °C/metre to 0.0129 ± 0.0013 °C/metre which is consistent with the view that the two sensors showed the same rate of temperature increase with water depth, since the difference in the two slopes is not greater than the sum of the standard deviations of the slopes (i.e. 0.002<0.0031). The intercept values for the sensors were 33.85 ± 0.17 ‰ and 33.79 ± 0.13 ‰. The two linear regressions give intercept, or starting points at surface waters, which are within 0.06 ppt of each other and since the sum of the standard deviations of the values is 0.30 shows that the different intercept values are statistically indistinguishable from each other, as would be expected from analyses carried out at the same time and same day on the same site.

Since the principal aim of the measurement of the properties of the water column was to determine the conditions on the *AE1* wreck site, the Excel cubic equation for the changes in salinity between 160-1,000 metres can be used to get an estimate of the salinity at the 350-metre depth. The cubic equations from both instruments gave a mean value of 35.04 ± 0.84 ‰ which gives, when combined with the calculated temperature of 11.6 °C gives a maximum dissolved oxygen content of 8.75 ppm.

**Figure 2 - Plot of the Variations with Water Depth with both Linear & Cubic Relationships**




The cooler waters at depth increase the dissolved oxygen content and the lower than average salinity also increases the solubility of oxygen, which is why the concentration of dissolved oxygen is as high as it is for a wreck at such a significant depth. By way of comparison the *AE2* wreck at 73 metres in the Sea of Marmara is at a salinity varying from 38-41 ‰ with dissolved oxygen levels at the depth of the wreck varying between 3-5 parts per million. Whilst the current on the *AE2* site was approximately 0.2-0.5 knots the reported current over the *AE1* was up to 3 knots. The higher dissolved oxygen and the higher current leads to increased flux of oxygen which means that, contrary to popular expectations, the depositional microenvironment of HMAS *AE1* is significantly more aggressive than the *AE2* which is waters that are five times shallower than her sister boat.

**Table 2 - Trend Line Analysis or fall in Sailnity with Water Depth 160 - 1,000 metres**

| 27530 intercept | 27962 intercept | 27530 depth correction | 27962 depth correction | 27530 $R^2$ | 27962 $R^2$ |
|---|---|---|---|---|---|
| 37.33 | 37.21 | -0.011d<br>+ 2 E-5 $d^2$<br>-7 E -9 $d^3$ | -0.011 d<br>+1 E -5 $d^2$<br>-6 E -9 $d^3$ | 0.9875 | 0.9831 |

With the curve fitting facility in Excel, the cubic equations that correlate the changes in salinity it was noted that the salinity is essentially constant after a depth of five hundred metres. Although the regression line gave a good fit and allowed calculation of salinity at the depth of the *AE1* wreck, the cubic equation is not readily interpretable in terms of the physical oceanography of the region.

A more detailed analysis of the decreasing salinity showed that rather than being a continuous function, the fall in salinity with depth was a logarithmic function i.e. it showed the same dependent parameter that the temperature did. A summary of the linear regression analyses of the logarithmic dependence on depth of the salinity is shown in Table 3 and in Figure 3. With the salinity data there was more of a divergence in the two sets of results, with somewhat different “turning points” in the log salinity vs. depth profiles which were subject to interpretation by the author of this report. The upper regions, beyond the initial linear increases in salinity as the dilution factor of the fresh water run off was overcome and the underlying salinity demonstrated its presence, showed a systematic fall in the log of the salinity with increasing depth. Both sensors gave a common range between 175 to 380 metres before the rate of

decline in salinity slowed down. The fall in salinity was steady at 1 x $10^{-5}$ (1E-05) for the next 200 metres for sensor 27962 while the sensor no 27530 showed a decrease in log salinity of double that of the other sensor up to a depth of 500 metres. Since the difference between these two slopes is ten times the sum of the standard deviations of the two slopes the differences are deemed to be significantly different. Owing to the data scatter both sensors showed the same log salinity intercept for the last 500 metres of the profile, but for SN 27530 at a very slow rate of fall at -7.7 x $10^{-7}$ per metre. For the sensor 27962 there was a slight increase in salinity of 3.0 ±2.4 E-07 per metre but essentially the salinity had reached a plateau region after 500-600 metres.

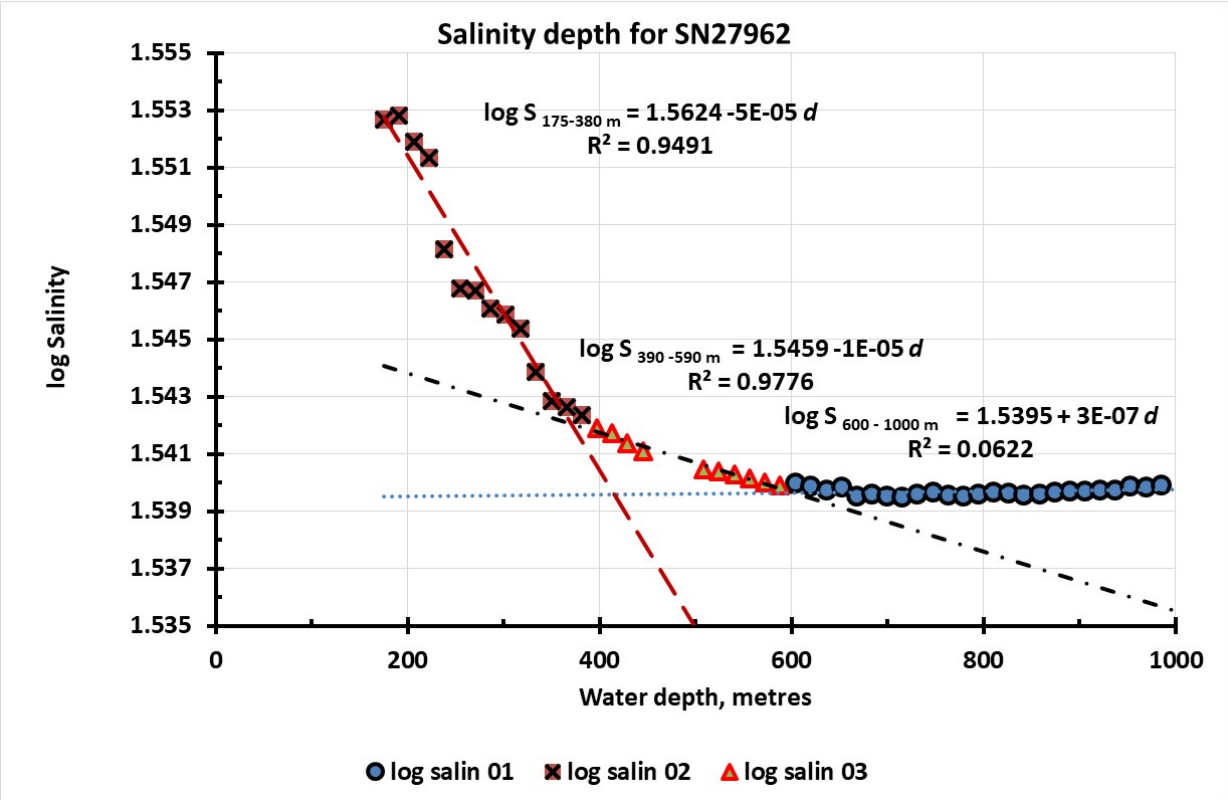
**Table 3 - Logarithmic Slopes of Salinity with Water Depth after 160 Metres**

| | intercept | slope / metre | $R^2$ |
|---|---|---|---|
| SN 27962 **175 - 380 metres** | 1.562 ± 0.001 | - 5 5 ± 0.4 E-05 *d* | 0.9490 |
| SN 27530 **175 – 380 metres** | 1.564 ± 0.001 | -5.7 ± 0.3 E-05 *d* | 0.9605 |
| SN 27962 **390 - 590 metres** | 1.546 ± 0.000 | -1 0 ± 0.01 E - 05 *d* | 0.9776 |
| SN 27530 **390 – 500 metres** | 1.551 ± 0.001 | - 2.1 ± 0.1 E-05 *d* | 0.9820 |
| SN 27962 **600 - 1,000 metres** | 1.541 ± 0.000 | + 3.0 ±2.4 E-07*d* | 0.0622 |
| SN 27530 **500 - 1,000metres** | 1.540 ± 0.002 | - 7.7 ± 2.5 E–07 *d* | 0.244 |

It is interesting to note that while the log of the seawater temperature fell linearly with depth for the first 470 metres and then the rate of fall slowed to one third its value as the depth increased to 1,000 metres, the turning point of the log salinity-depth appears to be around 380 metres then a second change occurs at 550 ± 50 metres. While the temperature slopes fell by a factor of three after the turning point at 470 metres the slopes of the log salinity depth profiles fell between a factor of 5 (27962) to the same three-fold change as the temperature sensitivity for sensor 27530. The similarity of the changes in slopes of the temperature and salinity indicates a common underlying feature, which is most likely the changing heat capacity of the seawater as salinity falls.

Inspection of the data in Table 3 shows that both sensors give the same intercept values for the log-salinity versus depth linear relationships, which indicates that part of the "error" associated with the different turning points is due to the choice of which data points should be included in any given linear regression.

**Figure 3 - Logarithmic dependence of salinity on water depth from 175-1,000 metres**



The overall salinity of the waters around New Britain are largely controlled by the movement of less saline water from the deep waters of the North Pacific Ocean from whence it flows past New Guinea and across Australia's north through Torres Strait and across Indonesia where it eventually meets up with currents in the North Atlantic Ocean (http://ocean.stanford.edu/courses/bomc/chem/lecture_03.pdf)

# 4 References

Butt, J. & Lindstrom, E., 1994, 'Currents off the east coast of New Ireland, Papua New Guinea, and their relevance to regional undercurrents in the western equatorial Pacific Ocean', *Journal of Geophysical Research: Oceans* 99(C6), pp 2156-2202.

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