Submerged Cultural Resources Study

USS ARIZONA MEMORIAL and PEARL HARBOR NATIONAL HISTORIC LANDMARK

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NATIONAL PARK SERVICE

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FOREWORD

At a time when more and more flashy, high-tech discoveries and salvage of long-lost undersea wrecks occur, this submerged cultural resource study of the Arizona Memorial is a refreshing change. The combined experience of the National Park Service's Submerged Cultural Resources Unit and the Navy's Mobile Diving and Salvage Unit One is remarkable, they are as expert at their business as can be found. What stands out, though, is that these talented divers sought and brought back for us all not artifacts, not souvenirs, not booty - simply knowledge. After the years of meticulous studies, foot-by-foot inspection and recording -- the USS ARIZONA and its sister ships all still rest secure, exactly as they were before this energetic endeavor began. You, too, can rest assured that these historic undersea relics will remain unimpaired. This is a classic study of how undersea explorations ought to be done so as to leave their historic subjects intact. In this publication, you have a thoughtful summary of the knowledge they gleaned.

Bryan Harry
Pacific Area Director
National Park Service

ACKNOWLEDGEMENTS

The work conducted on the USS ARIZONA and associated sites in Pearl Harbor was a complex undertaking. It involved cooperation among three major players: the U.S. Navy, the Arizona Memorial Museum Association and the National Park Service. Numerous individuals from each of these entities gave much of their time and energy to see the project through to its completion. Although this list is certainly not comprehensive, I would like to recognize some of these people for their efforts.

I won't dwell on individuals who have participated in authorship of this volume (including Gary Cummins and Bill Dickinson, Superintendents of the Memorial during the project), because their contributions will become apparent on reading the report. Several other employees of the memorial who continually gave much support to the project include Mark Senning, Farley Watanabe, Yvonne Menard, John Martini, Gary Warshefski, Ric Smith, Andy Johnson, Lisa DuPratt, Mark Hertig, Mary Martinez, Lisa Collins, Dick Hilgendorf, Lina Fuamatu, Jamie Parish, Mark Tenaka-Sanders and the late Fred Kukonu. Daniel Martinez conducted important background research for the project each year besides writing the historical research chapter. Ray Emory, Pearl Harbor survivor, researched potential sites for Japanese submarines and aircraft. In addition, all members of the memorial staff made our frequent visits to Pearl Harbor a pleasure, and they put up with the disruptions we caused in their daily routines with warmth and good humor.

Jerry Livingston, besides his role as chief illustrator, was responsible for formatting the document in a desktop publication system and preparation of much the camera-ready copy. Larry Murphy, besides being a co-author, was an important participant on the field level bringing his extensive background in underwater archelogy and his photographic skills to the project. Larry Nordby, Chief of the Branch of Cultural Research in the NPS Southwest Regional Office, made a major contribution in his 1984 field renderings of the USS ARIZONA, port and starboard elevations, which the volume illustrator has incorporated into the final five perspectives. This, in addition to work he accomplished for us in 1986, made Larry a key figure in the ARIZONA project. Dave McLean, NPS Diving Officer from Lake Mead National Recreation area, provided excellent daily coordination with Navy dive teams and was a valuable team member during all the field sessions. Jim Delgado, NPS Maritime Historian, obtained National Historic Landmark designation for both ARIZONA and UTAH, offered many helpful changes and additions to the historical record chapter and contributed a chapter to this report. Scott Henderson from the Naval Ocean Systems Center (NOSC), in addition to authoring a chapter, volunteered for followup dives to his

original research along with Jeff Grouvhog, also from NOSC. Jim Miculka, interpretive ranger from War in the Pacific National Historical Park, participated in the project and brought several volunteers-in-parks from Guam, including Joe Taitano and Suzanne Hendricks. Scott Lopez from Hawaii Volcanoes National Park participated frequently in the diving operations.

From the Arizona Memorial Museum Association, Gary Beito was very supportive of the survey work from its earliest stages. The clerks of the association bookstore were friendly to us despite our intrusive presence for weeks at a time over several years. The food and drinks donated by Concessionnaire Carol Lim are also appreciated. Pacific Area Director Bryan Harry, senior park service official in the study area, kept a quiet, watchful eye on the project as it unfolded but was ready to lend his support whenever necessary. This project also required smooth coordination between two NPS regional offices. Regional Directors of Western and Southwest Region (home office of SCRU) during the period the work took place were HowardChapman and Stan Albright (Western) and Bob Kerr and John Cook (Southwest). Roger Kelly, regional archeologist for Western Region played an active role each year in ensuring that this interregional coordination and cooperation held together. Chief archeologist of the National Park Service, Doug Scovill, has programmatic authority over the Submerged Cultural Resources Unit and strongly supported the Pearl Harbor operation. Cal Cummings, senior service archeologist in Denver, paid an on-site visit in 1986 and offered comparisons to work he was involved with on the USS MONITOR.

As will become apparent to the reader, the U.S. Navy was a close partner in this operation from the inception. We enjoyed active participation by U.S. Navy divers from Mobile Diving and Salvage Unit One (MDSU) and Explosive Ordnance Disposal (EOD) Mobile Unit One and Training and Evaluation Unit One in all phases of the research.

None of the activity would have taken place, however, without the sanction of Admirals Jeremiah, Anderson and Rorie, and Rear Admirals Boyle, Chadwick and Reimann. Commander Peck of MDSU supported the operation in the first few years. His successor, Commander David McCampbell, became intensely involved in the project and pulled out the stops in giving support to our operations; eventually, going beyond Pearl Harbor to various projects in Micronesia. In so doing, Commander McCampbell greatly advanced the concept of Project SeaMark, the name eventually assigned to the U.S. Navy/NPS cooperation on submerged resources work. That concept was first articulated by Commander James "Otto" Orzech as an active-duty training function for his reserve unit from Long Beach, California. Otto and his unit were primarily responsible for Navy support in the mapping of the USS UTAH, and Otto also was a major player in advancing the SeaMark concept to the Western Pacific. Commodore Rob Wells and Commodore David Wallace released fleet assets to assist NPS operations in Pearl Harbor and other joint ventures in the Pacific. Commander Steve Epperson provided services of his highly professional EOD divers for side scan and ordnance clearance activities on several occasions. Sub base support came from Captain Marshall. Lt. Michael Morrissey became an advocate for the SeaMark proposal with the Naval Surface Reserve Force in New Orleans and was largely responsible for securing funding for the work in 1986 at Pearl Harbor and later in Palau. Rob Hommon, archeologist with the Naval Facilities Engineering Com-

mand, provided coordination regarding matters of legal compliance with environmental legislation. Brian O'Connor, diver from MDSU One participated both in his Navy capacity and at other times as a volunteer diver and researcher.

The University of Hawaii, and Dr. Alex Malahof in particular, are thanked for contributing the use of a research submersible to the 1988 survey effort.

This manuscript was reviewed in draft form by Larry Nordby, Doug Scott, archeologist with the NPS Midwest Archeological Center, Don Boyer with the Bureau of Land Management in Santa Fe, Neil Mangum, NPS Historian in Santa Fe, Chief Historian of the National Park Service, Ed Bearss and his staff including Kevin Foster, Jim Charleton and Jim Delgado. Joy Murphy did a technical edit of the contents. Fran Day, SCRU secretary, was responsible for typing the manuscript and mastering the interplay of several word processing systems.

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CHAPTER I

INTRODUCTION

On Dec. 7, 1941 the United States of America became directly involved in the greatest of human conflicts: World War II. Even before bombs fell on Pearl Harbor that Sunday morning, it was clear to many Americans that they would soon be at war with Japan. What was unexpected was the seemingly apocalyptic nature of the sneak attack. It was an event that emblazoned itself in the minds of millions of Americans, a passionate, inflamed response alive even today, spanning generations. The single most powerful image associated with the Pearl Harbor attack was the twisted, smoking metal and mast of the USS ARIZONA.

In 1983 the Submerged Cultural Resources Unit (SCRU) was tasked with mapping and photo-documenting the remains of the USS ARIZONA in its final resting place in Pearl Harbor. Superintendent Gary Cummins was responsible for managing a major national shrine, one that he couldn't see and for which there existed no management precedents. During the war Navy salvage teams had cut away most of the ship's superstructure. Eventually a memorial was built over the sunken ship's hull that is the grave of approximately 1,000 U.S. servicemen. Cummins wanted to know what sort of integrity the hull retained. Was it in imminent danger of falling apart? Where was the oil coming from that leaked so conspicuously from the ship? Did armament or live ordnance still exist in the wreckage? He asked those and a host of other questions that boiled down to "What's there?" It was perfectly clear what had been there before Dec. 7 1941, but notions regarding its present condition were riddled with contradiction and mystery.

SCRU conducted a 10-day site assessment with assistance from park staff, the Arizona Memorial Association, and the U.S. Navy's Mobile Diving and Salvage Unit (MDSU) One in Pearl Harbor. Information gleaned from the 1983 assessment was used to plan comprehensive mapping operations that took place in 1984. This preliminary operation also dramatically illustrated how little was known of the ship's remains. The entire No. 1 turret with its 14-inch guns intact (which were believed to have been salvaged) was discovered by the first divers, as was a profusion of live 5-inch shells directly under the memorial structure. The latter were immediately removed by a Navy Explosive Ordnance Disposal (EOD) team.

The three weeks of intensive diving in 1984 produced sufficient data to complete a planimetric view of the ship, as well as drawings of the port and starboard elevations of the hulk. Drawings were finalized in winter 1984 and released in 1985 by SCRU in a five-part format that included two additional artist's perspectives from the port and starboard quarters. Jerry Livingston was responsible for the final rendering, which subsequently received the John Wesley Powell prize for Historic Display.

In September 1985 Bill Dickinson became superintendent of the Arizona Memorial and resolved to continue research diving on the ship. He felt that the 1985 drawings had satisfactorily answered the question of "what's there?" but he was anxious to proceed with the next step in a logical research progression in order to determine "what's happening to what's there?" Before leaving his post, Cummins had suggested a corrosion study. Dickinson broadened that concept to include a full inventory of the biota and the relevant chemical environment around the hull that might influence long-term preservation. Both managers had come to realize during their tenure that the USS ARIZONA was essentially a large, multicompositional metal structure resting in a biochemical soup, and many more questions needed answering before they could confidently exercise proper stewardship over the site. It soon became clear that the first challenge in the process of obtaining good answers was to ask good questions, the parameters of which stretched across managerial and scientific disciplines.

Dickinson and the memorial staff spent much of winter 1985 and spring 1986 coordinating with SCRU, the University of Hawaii and the Naval Ocean Systems Center (NOSC) on the research design for a field operation scheduled for June of that year. As in prior years, Dan Lenihan would be overall director of research operations, but primary responsibility for the biofouling aspects of the study lay with Scott Henderson from NOSC.

The 1986 endeavor would be especially complicated because of several developments. Robert Sumrall, a ship modeler from Annapolis, was contracted to construct a model of the USS ARIZONA on the harbor bottom from the 1985 drawings produced by SCRU. To do so, Sumrall needed more information from the planimetric or "bird's eye" view, one of the five perspectives produced by the earlier work. To provide additional detail, it was decided to resurvey that "bird's eye" view of the site and add objects lying on the deck that might have been overlooked previously.

Another event that altered the course of the 1986 research was an encounter between Lenihan and a U.S. Navy Reserves officer at the fall 1985 meeting of the American Academy of Underwater Sciences. There Commander James "Otto" Orzech expressed great interest in the project because it seemed to be a realistic training exercise for his detachment of reserve Navy divers from Long Beach, California. He agreed to assist with the task of mapping the USS UTAH, which was lying on its side on the other side of Ford Island from the ARIZONA. Orzech's unit would participate as part of the unit's active-duty training at no cost to the National Park Service, if the Service could provide underwater and topside supervision of the research.

By now all the principal players realized that the most meaningful context to present the results of the ARIZONA study would be the Pearl Harbor attack. Describing that context would involve research in other parts of Pearl Harbor, but it was unclear where the funding would come from for operations outside the park boundary. The UTAH was the only other ship that remained from the attack. Japanese planes and submarines were believed to be on the harbor bottom. Documenting all those would be logical steps in completing the Pearl Harbor story from an underwater perspective. With support from the active-duty Navy at Pearl and the Long Beach Reserves unit, and the continued backing of the Arizona Memorial Museum Association, they now became realizable objectives.

A final element that raised the complexity and intensity of the 1986 field operations was the British Broadcasting Corporation (BBC), who felt that the research was important and merited inclusion in a major public television series, titled "Discoveries Underwater." Consequently, when the three-week session began in June, logistics involved coordinating Navy, National Park Service and BBC dive teams. Lenihan assigned SCRU Archeologist Larry Murphy oversight responsibilities for the UTAH site and Larry Nordby the task of revising the planimetric view of the ARIZONA. NPS divers from the memorial staff who were veterans of the three previous project phases were assigned to work with Scott Henderson. To the surprise of many, the project progressed smoothly and effectively, and all major objectives were achieved. It was decided early in the project, however, to postpone any search for Japanese aircraft lost in the attack because it would overextend the SCRU staff, which was by then supervising the research activities of 60 divers at two separate sites under a complex research design.

In 1987 the USS UTAH documentation was completed. In a comparatively low-key operation, a small contingent of Navy divers from the Long Beach unit assisted Lenihan and Jerry Livingston in obtaining final details on the target ship. During that time Bill Dickinson also used the dive team -- supervised from the surface by a structural engineer -- to conduct an underwater survey of the mooring chains for the memorial's floating dock. The results of that survey will be reported separately.

The research project had expanded to be a full submerged cultural resources study of World War II remains in Pearl Harbor. The final phase occurred over a three-week period in 1988. Daniel Martinez, a staff historian at the memorial, in 1986 developed a predictive model for airplane crash sites, based on cross-sitings from different vessels during the attack. The model isolated high-probability areas by matching sitings of splashdowns and high-velocity crashes with an assessment of post-war dredging reports. Active-duty MDSU One divers from Pearl Harbor were assigned to survey the predicted crash sites. In addition, a side-scan sonar team from EOD One in Pearl Harbor was assigned to the project. Under the leadership of Lieutenant Hank Chace, EOD was to survey the inner harbor for planes. EOD was also assigned to search the 1,000+-foot-deep defensive perimeter outside the harbor mouth for a Japanese mini-sub reportedly sunk by the destroyer USS WARD more than an hour before the aerial attack began. The submarine base at Pearl Harbor provided major boat and logistic support, and Mesotech Corporation donated a sophisticated sonar unit to help in the inner harbor. Background research for that survey was provided by Ray Emory, a USS Arizona

Figure 1.1. Gary Cummins, Superintendent of ARIZONA Memorial inspects embrasures of No. 1 turret. It was not known that the 14-inch guns were still in place on the ship until the underwater survey. (NPS photo by Larry Murphy)

Figure 1.2. The USS ARIZONA from the air. Note that 14-inch guns of No. 1 turret are not visible. (Photo courtesy of Hawaiian Service, Inc.)

Figure 1.3. *NPS and Navy divers deploy from the tour boat dock. Operations were so visible to visitors that park staff discussed the survey in their interpretive talks. (NPS photo by Larry Murphy)*

Figure1.4. *An already complex operation in 1986 was further complicated by the addition of a BBC camera team that filmed the operation for a public broadcasting system special (NPS photo)*

Memorial volunteer and Pearl Harbor survivor, with assistance from Daniel Martinez and others on the memorial staff, and Brian O'Connor, a U.S. Navy diver. The survey in the inner harbor was grueling but effective, and yielded primarily negative data returns. In the eleventh hour of the offshore operation, however, a sonar contact was made with what may well be the midget submarine sunk by the USS WARD. At the time of this report the identity of the contact has yet to be confirmed, although an attempt was made to locate it with a submersible provided by the University of Hawaii.

Accomplishments By Year

1983
: Assessment dives were conducted for 1 1/2 weeks and video documentation begun.

1984
: Site was completely surveyed in order to render the site in an architectural style from three perspectives: planimetric view, starboard and port elevations. Site was completely videotaped for interpretive and archeological purposes.

1985
: All data from 1984 field operations were rendered into final drawings.

1986
: A. Biofouling/corrosion study was conducted on the ARIZONA.
: B. Planimetric view was resurveyed in greater detail.
: C. The UTAH was surveyed.
: D. BBC filmed the project for international broadcast.

1987
: Final data from the USS UTAH was obtained, and mooring chains of the USS ARIZONA were surveyed for structural integrity.

1988
: Pearl Harbor was surveyed for other remains of the attack, including mooring quays and plane crash sites. A search was made for mini-sub sunk by the destroyer USS WARD. Unsuccessful attempt made to confirm sonar contact on mini-sub by University of Hawaii submersible Pisces 5.

Project SeaMark

From its earliest stages, the research on the USS ARIZONA involved a partnership between the US Navy and the National Park Service. This alliance was initiated the first year by Superintendent Gary Cummins, who inquired if any Navy diving personnel at Pearl Harbor might be available to assist National Park Service specialists in underwater mapping operations. Reservations about mixing different agency diving policies -- and different diving teams -- proved to be unfounded. The teams quickly melded resources and worked efficiently together within the confines of their respective guidelines. This partnership became an important tradition in the ARIZONA research over the years, eventually having implications for the two agencies well beyond Pearl Harbor.

After the cooperation between NPS divers and the active Navy in 1983 and 1984, the way was paved for more cross-fertilization. The U.S. Navy Reserves became involved with SCRU in 1986 when Detachment 319 from Long Beach, California, led by Commander Orzech, volunteered its services. That unit completed active-duty training requirements by working on the USS ARIZONA and the USS UTAH.

Figure1.5. BBC cameraman John Beck (in glasses) coordinates underwater filming sequence with Project Director Lenihan. (NPS photo by Larry Murphy)

Figure 1.6. NPS Diving Officer, Dave McLean, discusses dive sequencing with Scott Henderson from Naval Ocean Systems Center. (NPS photo by Larry Murphy)

In 1986 Commander David McCampbell became the commanding officer of MDSU One, and his commitment to this cooperative program became a major factor in its remarkable growth. In 1987 the NPS/Navy diving alliance expanded to include four naval reserve units working in Guam and Hawaii. Other naval units teamed up with NPS divers in Cape Cod National Seashore and Golden Gate National Recreation Area.

By 1988 nearly the entire US Navy mobile diving and salvage community, including all 14 reserve units, spent part of its active-duty training with NPS documenting historic shipwrecks. They took on historic-preservation tasks from the Republic of Palau in the Pacific to the Statue of Liberty National Monument in New York Harbor. The interagency arrangement now had a name: Project SeaMark. In 1989 we are attempting to institutionalize it by a formal memorandum of agreement between the Chief of Naval Operations and the Director of the National Park Service.

Research Design

The role played by modern warfare in human conflict resolution has been the focus of anthropological inquiry for some time (e.g., Bohannon 1967, Muckleroy 1978, Gould 1983). The remains of the USS ARIZONA, the USS UTAH, the Japanese planes and submarines that initiated the attack and even the bullet holes in the buildings of Hickam and Wheeler fields, comprise a material statement that archeologically and symbolically preserves the reality of World War II in a manner that could never be replicated by books, films or pictures.

The guiding principle for all phases of this project was to document archeological remains of the attack and to relate the findings to the popular notions of what had happened, as gleaned from the historical record.

Research design statements were developed for each phase of the Pearl Harbor work. The design changed as the objectives expanded from a straightforward mapping operation of the ARIZONA to include an interpretive video program, structural integrity study, documentation of the USS UTAH and a general survey of WWII remains in, and immediately outside of, Pearl Harbor.

An overriding theme for the researchers was to generate information useful to managers responsible for stewardship of a major American war memorial. The documentation process itself became a tool for further educating the public to the significance of the site, and for generating new insights into the human dynamics involved in modern warfare among industrialized societies.

The challenge was to archeologically document the material remains of the attack in a manner that was accurate as to ship architecture, and also sensitive to the minor details that could be helpful in understanding human behavior in a comparative framework. For this reason, even modern debris lying on the deck was recorded by the team as an integral part of the site.

Among the technical problems was developing an image of a 608-foot battleship on the harbor bottom with very little relevant documentation available. Although some plans exist, many of the operational modifications were not well-documented, nor were any of the traumatic changes to the hull that resulted from the attack or the extensive salvage that followed.

Furthermore, the research design had to be totally nondestructive in nature, both in the documentation phase and also in the search for new materials in the harbor.

Low-impact, low-tech methods were chosen that utilized a large number of personnel skilled in diving but possessing no scientific background. A detailed discussion of the methods used in each phase of the documentation research is presented in Chapter III.

Relevant questions were particularly hard to define for the corrosion and biofouling study, even the type of experts necessary. Many scientists have addressed the problems of metal corrosion but rarely with the variables encountered at Pearl Harbor: an immense steel object with water on both sides of the plates, existing in an environment rich in biological organisms and full of stray currents from many possible sources. The water was presumably aerobic on the hull's exterior but the oxygen content of water in the interior was unknown. The hypotheses generated for determining relevant variables and for eventually being able to roughly predict the implications for structural failure are discussed in detail in Chapter IV.

Research parameters for the discovery-phase survey for sites in the harbor involved development of a predictive model, which is presented in the historic record narrative in Chapter II. Discussion of the deep-water side-scan survey methodology is in Chapter III, while the corresponding predictive model falls in Chapter II.

Archeology of War

Richard Gould in Shipwreck Anthropology (Gould 1983) discusses a range of issues pertaining to the archeology of war that are germane to the Pearl Harbor research. Gould states that examination of material remains of battles enhances our understanding of human behavior in warfare, providing more information than an exclusive dependence on written or oral history. Societies have certain responses to the stress of warfare and the anticipation of warfare that are not totally conscious, and that correspond more to general laws of human behavior. These behaviors leave signatures in the material record that serve as "unambiguous indicators and identifiers of the particular kinds of behavior that produced them" (Gould 1983:106).

To illustrate his case, Gould compares the battle of the Spanish Armada in 1588 with the Battle of Britain in 1940, and offers a proposition: "The greater the defensive isolation of the combatants, the greater will be the efforts by that combatant to salvage and recycle items and/or materials of strategic value from any wrecks that fall within its territory."

Building on Gould's paradigm, the residues of the Pearl Harbor attack show clearly a high degree of stress on the part of the American Pacific Command. Although the United States was certainly not in a desperate position regarding its military-industrial potential to rebuild fleet losses, its response was very much in line with behavior Gould would ascribe to an isolated combatant. One of the most intense salvage operations ever undertaken ensued at Pearl Harbor over the two years after the attack. Hawaii is isolated by 2,500 miles from the U.S. mainland, and within what the Japanese considered the aegis of the Greater East Asia Co-prosperity Sphere (Stephan 1984).

It may be that the signs of intensive salvage and recycling evident all through the ARIZONA's remains result from a sense of strategic vulnerability. That does not explain, however, why so many of the easily salvaged items of ship's apparel, armament and groundtackle on the UTAH were left in place. Perhaps the very nature of the ARIZONA as a memorial and its symbolic significance to the American people explain the salvage behavior of 1942.

This dual nature -- archeological site and war memorial -- is not restricted to the material remains at Pearl Harbor. The duality creates a particularly compelling research focus for archeologists and historians because of the symbolic lode of the remains. Historian Edward Linenthal has offered instructive observations on the role of the battlefields as reservoirs of spiritual power.

> For many, the Little Big Horn was one of America's sacred places, hallowed by the blood of America's warriors. As a sacred place, the Little Big Horn is part of a constellation of martial centers where Americans celebrate the formative acts that give shape to the nation. Gettysburg, the Alamo, Lexington, and Concord are all places of power, power that can be ritually recalled (Linenthal 1983:268).

Archeologists, as students of human behavior, would miss a great deal if they failed to recognize the normal transformational processes that make the USS ARIZONA and USS UTAH what they are today are largely conditioned by cultural perceptions of the sites. An entity composed of steel and silt and encrusting marine organisms has become something more than an object -- it is now a "place." People visit this place, build structures over it and venerate it much as one venerates a religious relic. This role as secular shrine is an important one in a society that has become increasingly detached and even cynical in regard to its military accomplishments.

It would be interesting to monitor over time the manner in which Americans treat this site as a shrine. If we stay far from the spectre of contemporary warfare, will its importance fade? Will distance increase its power? Will the memorial tend to serve as a barometer of the general sense of social well-being? It may be hypothesized, in the sense of Linenthal, that Americans will draw upon this site for strength as if it were a reservoir of spiritual power, less intensely in times when the perceived threat is reduced. In any event, the archeology of the historic remains at Pearl Harbor doesn't end with this descriptive report. A study conducted 100 years from now by archeologists of an anthropological persuasion will probably tell us a great deal more about how our society deals with its mythic sense of the past and its role in warfare with other nations.

Analogs

In most respects the USS ARIZONA presents a unique historic-preservation problem, but there are some parallels, notably the USS MONITOR. The MONITOR lies about 200 feet deep off Cape Hatteras, North Carolina. At such a remote location, the ship is not visited by the public, yet it does raise many management issues similar to the ARIZONA.

The vessel played a significant role in American history, is a symbol to the American people and is also a war grave. It is a metal shipwreck whose preservation parameters are presently being determined. The National Oceanographic and Atmospheric Administration (NOAA) manages the site, the first National Marine Sanctuary under its jurisdiction. To date, research on the MONITOR has been directed toward mapping the ship and assessing its condition, much like the ARIZONA. One significant difference is that NOAA has proceeded with the avowed long-term objective of eventually removing the ship or portions of it. No such goal is entertained by the managers of the ARIZONA.

Perhaps the only other sunken metal warship that is the focus of similar attention is HMS ROYAL OAK in Scapa Flow, Great Britain. Sunk by a German submarine in a surprise attack, this ship is treated as a war grave by the British, but no active management steps are taken to interpret, or encourage visitation to, the site. An annual ceremony takes place over the ship, but the philosophy is definitely one of benign neglect. There is no intent to research the vessel or in any way interfere with the natural process of deterioration.

The disposition of shipwrecks of symbolic and historical importance is an issue that will become increasingly compelling as time goes on and as technology for undersea exploration advances. The discoveries of the RMS TITANIC in 1985 and the KMS BISMARCK in 1989 dramatically underscore this issue: Our ability to find historical shipwrecks is advancing faster than our ability to intelligently care for them once found.

This Report

This monograph is one in a series of reports that emanate from the offices of the Submerged Cultural Resources Unit in Santa Fe, New Mexico. Intended to fulfill several functions, it is primarily a source document for managers and researchers who will be involved in future stewardship of the USS ARIZONA and other period resources in Pearl Harbor. This document discusses the road thus far traveled and suggests future directions. It becomes a milestone of sorts in the administrative history of the USS Arizona Memorial and serves to define explicitly the values believed worthy of protecting and interpreting in a national context.

This report also fulfills professional researchers' obligations to be explicit about what they did and why they did it. Their data permits a realistic evaluation of the research process by other professionals. The report also ensures the survival of the knowledge gained in a way that allows cumulative understanding, which is the ultimate pursuit of all scientific inquiry. For the general public, the following is a guide so readers may select chapters of greatest interest to them.

Chapter II discusses the history of the Pearl Harbor attack and complements the discussions of the archeological record presented in Chapter III. It is written by Daniel Martinez, who has served as an interpreter and historian at the Arizona Memorial for many years. Daniel emphasized the aspects of the attack that enriched our understanding of the remaining archeological vestiges in the harbor. Consequently, heavy emphasis is given to the USS ARIZONA and USS UTAH because they are the only two vessels still remaining, although we acknowledge that many others played important roles in that historic event. Historic photos credited to "NPS: USAR" in this section are from the photo collection maintained at the Memorial by the National Park Service. This chapter should interest a general reading audience.

Chapter III discusses the archeological method, activities and results. It emphasizes analysis and description of the remaining fabric of the ARIZONA and the UTAH from the perspective of an imaginary swim through the sites. It is written by the volume editor, Dan Lenihan, who was principal investigator for all phases of the field studies, and by Larry Murphy, a SCRU Archeologist who was intimately involved with the design and implementation of the project from the beginning. This chapter may be of general interest but tends to be more technical than Chapter I and II and is directed to a professional and managerial audience.

Chapter IV, a highly technical chapter that covers the special study of biofouling and corrosion conducted in 1986, was written by Scott Henderson of the Naval Ocean Systems Center in Hawaii. The chapter is aimed at scientists and park managers who face similar management issues.

Like most products of the Submerged Cultural Resources Unit, this document reflects a blending of the objectives of park managers with those of cultural-resource specialists (archeologists, historians and anthropologists). Chapter V focuses on the unique perspectives of the managers ultimately responsible for the site's disposition. Gary Cummins and Bill Dickinson served as consecutive superintendents of the USS Arizona Memorial from the beginning of the National Park Service stewardship to 1988. In this chapter, they describe the process of learning the nature of the resource they were managing and developing strategies for monitoring and caring for it. This chapter, although aimed at fellow managers, should prove interesting to most readers.

Chapter VI presents a framework for understanding the significance of various submerged remains of the Pearl Harbor attack as part of our national heritage. This chapter is written by National Park Service Maritime Historian James P. Delgado, who nominated all the sunken vessels thus far designated as National Historic Landmarks, including the USS ARIZONA and USS UTAH. This section of the report will particularly interest World War II historians and managers of war memorials who deal on a daily basis with public perceptions regarding worth and importance. It will also be informative to the anthropologist studying symbols and icons in American culture.

CHAPTER II

HISTORICAL RECORD

Introduction

The purpose of this chapter is to provide a historical context for World War II remains in Pearl Harbor. As discussed in Chapter I, the research project reported here primarily documented the archeological materials remaining from the December 7 attack. In order to understand the significance of these materials as cultural resources, it is important to place them in their contemporary historical context.

As is the format for historical/archeological studies, the discussion will focus primarily on remains that are known or suspected to be still present in the archeological record. The degree of emphasis placed on discussion of individual ships, events or places has been strongly influenced by what sites the archeologists chose to concentrate their energies on during the survey.

In addition to the remains directly attributable to the attack, a discussion of the West Loch disaster that occurred in 1944 is also included. This event is thought to be a major contributor of additional World War II remains to the universe of potential sites that might be encountered in the harbor.

The Pearl Harbor Attack

Nationalistic and militaristic fervor in Imperial Japan and a strong belief in Japan's destiny and divine right to rule all of Southeast Asia brought Japan and the United States into increasing diplomatic confrontation throughout the 1930s. Compounding the matter was a bloody undeclared war the Japanese were waging in China and the weakening of European control in Asian colonies as a result of the Second World War. The signing of the Tripartite Pact in September 1940, which allied Japan with Germany and Italy, aggravated tensions between the United States and Japan as the latter nation joined the Axis Powers. When Japan seized a major portion of Southeast Asia under agreement with Vichy France, the administration of President Franklin D. Roosevelt was moved to action. Already outraged by Japanese aggression in China, the Roosevelt administration introduced economic sanctions to make its point clear: The United States would not facilitate Japan's expansion into the Pacific, just as it opposed German expansion in Europe. An American embargo cut off shipments of scrap steel, raw materials, oil and high-octane gasoline, while freezing Japanese financial assets in the United States. The Japanese, having only a six-month supply of strategic fuel available for its armed forces, felt the only choice was to initiate the conquest of Southeast Asia, which meant inevitable war with America, Britain, and the Netherlands. Japan had seen the United States expand its naval authority in the Pacific in the late 1930s. The bolstering of defenses in the Philippines, Hawaii, Guam, Midway and Wake Island, as well as stationing the United States Pacific Fleet at Pearl Harbor, made America the first priority for a Japanese attack.

Fearing that the U.S. Pacific Fleet would pose a formidable obstacle to Japanese conquest of Southeast Asia, Admiral Isoruko Yamamoto, the commander in chief of the Japanese Combined Fleet, visualized a bold attack on the Pacific Fleet while it lay at anchor at Pearl Harbor. Such a "surprise strategical" attack, bold and daring in its execution, would secure the Pacific and initiate the war, following in the tradition of the Japanese naval victory over the Russians at Port Arthur in 1904 and the opening maneuvers in Japan's invasion of China. Although nationalistic and militaristic pride was driving Japan inexorably toward war with the United States, some military leaders were concerned about the long-range implications of a protracted war with an industrial giant. Yamamoto expressed doubt, apprehension and disgust over Japan's headlong push toward conflict. In January 1941 he wrote to Ryoichi Sasakawa, who was the president of Japan's rightist nationalistic organization Kokusai Domei and one of Yamamoto's staunch supporters:

> . . . if there should be a war between Japan and America, then our aim, of course, ought not to be Guam or the Philippines, nor Hawaii or Hong Kong, but a capitulation at the White House, in Washington itself. I wonder whether the politicians of the day really have the willingness to make sacrifices, and the confidence, that this would entail? (Agawa 1979:291)

Thus the admiral who was about to initiate the opening attack of the war revealed his personal attitude. Although he was reluctant to push toward war, he possessed a strong sense of duty. With Japanese policy indicating that war was now inevitable, Yamamoto took a hard look at the navy and Japan's chances, noting he expected to "run wild" for six months, with the outcome after that up in the air. In order to hit U.S. forces so hard that America would seek a quick peace, Yamamoto explained to Navy Minster Koshiro Oikawa, "We should do our very best . . . to decide the fate of the war on the very first day." He described his operational plan to attack Pearl Harbor.

The plan had been mentioned before. In the spring of 1940 Japan's air fleet had conducted aerial torpedo exercises under the watchful eyes of Yamamoto and Rear Admiral Shigeru Fukudome, head of the first division of the naval general staff. In passing conversation, almost in a whisper, Yamamoto had said, "I wonder if an aerial attack can't be made at Pearl Harbor?" (Prange 1981:14). Even then, the thought was not new. Exercises by both countries had played out such a scenario, but both Japan and the United States believed an aerial torpedo attack on Pearl Harbor was impossible. The actual plan of operation, formulated by a young tactical genius in aerial warfare, Commander Minoru

Genda, was agreed to after months of internal dissension among the ranks of command in the Japanese navy. When negotiations with the United States were deemed unsatisfactory to the Japanese government of Prime Minister Hideki Tojo, official blessing was sought for the "Hawaii Operation." It was given on September 6, 1941, at an Imperial Conference. Japan was committed to war.

The First Air Fleet had held maneuvers for almost a year, and the results were promising. Under the direction of Commander Mitsuo Fuchida, who would lead the air assault on Pearl Harbor, the "impossible" task of an aerial torpedo attack was made possible. Conventional aerial torpedoes plunged to more than 100 feet in depth and ran a long distance to arm. The 45-foot average depth of Pearl Harbor and the short runs necessary to sink ships there were dealt with by adding wooden fins to the torpedoes, altering the arming devices, and by training in simulated conditions.

A task force of 32 vessels -- particularly the carriers AKAGI, HIRYU, SORYU, KAGA, ZUIKAKU and SHOKAKU -- was dubbed the "Kido Butai" (Strike Force). Secretly assembling on Tankan Bay in Northern Japan, the force was placed under the direct command of Vice Admiral Chuichi Nagumo. At 6:00 a.m. on November 26, 1941, the Japanese fleet weighed anchor and slipped out to sea for Hawaii. In planning the operation, the northern approach to Hawaii had been selected even though the weather and seas would be rough. The winter storms would mask the Japanese fleet and lessen the chances of encountering the enemy while on the high seas. A screening force of submarines traveled 200 miles ahead, and as the fleet approached Hawaii, it received up-to-date reports from agents on Oahu as well as the submarines, which finally were picketed around the islands. On December 2 a coded message arrived in Tokyo: "Climb Mt. Nitaka." This pre-arranged message signaled the final decision to wage war. The fleet was to press forward and attack on Sunday, December 7, 1941, Hawaii time.

At 6:00 a.m. on December 7 the Japanese fleet was 230 miles north of Oahu. Six carriers turned into the wind and launched the first wave -- 185 planes. At the launching, two Zero fighters dropped from the mission: One crashed into the sea on takeoff, another developed engine trouble and was left on board the carrier. At 6:20 Commander Fuchida led the first wave of planes toward Pearl Harbor.

As soon as the first wave departed, the carrier crews readied the second wave. At 7:05 the carriers again swung eastward into the wind and began launching 170 aircraft. As before, the first lift-offs were the Nakajima B5N2 "Kates," which served as torpedo bombers on the first wave, and as horizontal bombers on the first and second waves. The Kates were followed by the Aichi D3A1 "Vals" (dive bombers) and Mitsubishi A6M2 Reisen Zero fighters. One Zero and two dive bombers developed engine trouble and failed to make the trip, leaving 350 planes in the air.

Meanwhile on Oahu, two warnings of the impending attack occurred. In the waters just outside the entrance to Pearl Harbor, the destroyer WARD at 6:45 a.m. fired on, depth-charged and sank a submarine within the defensive sea area. Bureaucratic delays and the need for confirmation caused an hour to go by before the report was forwarded to Admiral Husband E. Kimmel, commander in chief of the U.S. Pacific Fleet.

The second warning occurred at 7:02 a.m., nearly half an hour after the WARD fired the first shot of America's Pacific War. Two Army radar operators at the Opana station above Kahuku Point on Oahu's north shore picked up a large formation of planes on their radar screens. After checking and rechecking equipment, they notified the watch officer at Fort Shafter. No action was taken because the officer believed the planes to be a flight of B-17s flying in from California.

Flying above thick cloud cover, Commander Fuchida thought for a moment he had overflown Oahu, but a sudden parting of the clouds revealed the island's north shore. The signal was given to assume attack formation. As Fuchida looked toward Pearl Harbor and the surrounding airfields, he was relieved to see that the attack was a surprise, and the earlier report of Kido Butai's scout plane "Enemy formation at anchor!" was accurate. To Fuchida's disappointment, the prime targets of the attack -- the aircraft carriers -- were absent. Changing their plan, the torpedo planes concentrated on the battleships lined up along Battleship Row and the east side of Ford Island.

With assignments memorized by constant training, the first wave of planes attacked at 7:55 a.m. At about the same time, fighters and dive bombers hit the airfields at Kaneohe, Hickam, Ewa, Bellows and Wheeler. Within two hours, most American air power in Hawaii was neutralized.

At Pearl Harbor, as morning colors were readied and sailors and civilians ate breakfast, the Japanese planes struck. In 15 minutes the main battle line of the Pacific fleet was neutralized. The battleships CALIFORNIA, OKLAHOMA, WEST VIRGINIA, NEVADA and ARIZONA were sunk, as was the old battleship UTAH then being used as a target and antiaircraft training vessel. The battleships MARYLAND, TENNESSEE and PENNSYLVANIA were damaged. Initially, the American response to the attack was sporadic, but within five minutes American vessels began to fire back in earnest against the attackers. "Air Raid Pearl Harbor, this is no drill!" was relayed to the fleet.

The assault of the first wave ended about 8:45 a.m. There was a momentary lull before the second wave of Japanese planes arrived at 8:50 a.m. No torpedo planes came with the second group of dive and high-altitude bombers.

As the second wave withdrew, Fuchida circled Pearl Harbor and assessed the damage. Satisfied, he took a last look and signaled his pilots to return to the carrier. The main objective of the attack -- demobilizing the Pacific Fleet -- had been accomplished. More than 2,400 Americans were killed and 1,104 wounded. Twenty-one vessels of the Pacific Fleet had been sunk or damaged, and 75 percent of the planes on the airfields surrounding Pearl Harbor were damaged or destroyed.

It was nearly 10 o'clock when the first wave of Japanese aircraft began landing on their carriers. By noon, the last planes had been recovered. Twenty-nine Japanese planes were lost, along with 55 airmen. The Special Attack Unit of midget submarines had lost 10 crewmen and all five boats, one boat and one prisoner were captured by Americans the following day on the beaches near Bellows Airfield.

Fuchida was gratified to see planes being readied for a third assault because many targets had been left untouched, particularly the naval shipyard, oil-storage facilities, and a number of American ships. While he wondered when the third wave would be launched, a heated debate was underway on the bridge of the fleet flagship HIJMS AKAGI.

Admiral Nagumo had feared the operation would not be successful, yet he had achieved successful results with minimal casualties. It was his contention that the mission was accomplished. Furthermore, the fleet's fuel was running low. More important, American carriers and

Figure 2.1. Japanese carriers SORYU and AKAGI readying carrier launch. Date unknown. (NPS: USAR collection)

Figure 2.2. Japanese torpedo plane (Kate) takes off from flight deck of unknown carrier. Date unknown. (NPS: USAR collection)

Figure 2.3. Destroyer SHAW explodes. The USS NEVADA is seen to right. Photo taken from Ford Island. (NPS: USAR collection)

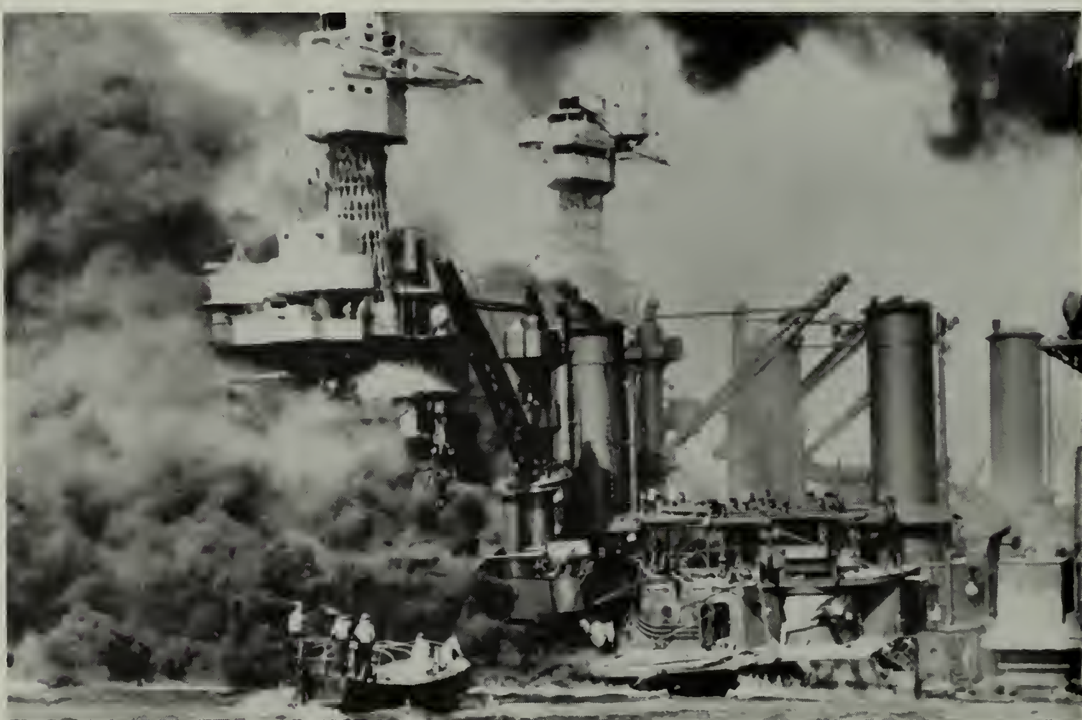


Figure 2.4. WEST VIRGINIA and TENNESSEE in background as launch speeds to rescue survivors. (NPS: USAR collection)


Figure 2.5. Photo early during first wave assault. Note P-40 fighters afire. (NPS: USAR collection)


Figure 2.6. Photograph taken right at beginning of attack from Japanese planes. Note aircraft over Battleship Row and torpedo hit on USS OKLAHOMA.. (NPS: USAR collection)

Figure 2.7. Oblique perspective on Battleship Row from attacking Japanese plane. (NPS: USAR collection)

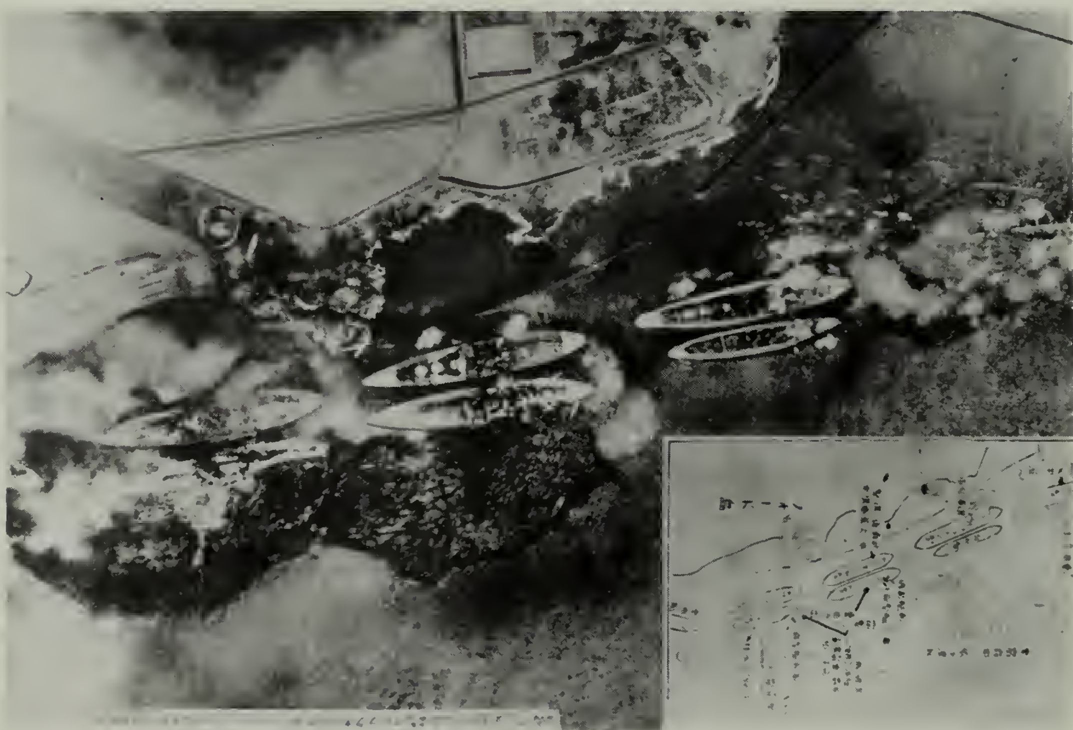


Figure 2.8. Overhead perspective of same. (NPS: USAR collection)

Figure 2.9. Japanese plane flies over submarines USS TAUTOG (left) and USS NARWHAL (right). (NPS: USAR collection)

Figure 2.10. An arch of billowing smoke emanates from the USS ARIZONA. WEST VIRGINIA and TENNESSEE are in the center of photo. (NPS: USAR collection)

Figure 2.11. Small craft and fireboat assist the USS WEST VIRGINIA in fighting fires. The USS TENNESSEE in background. (NPS: USAR collection)

Figure 2.12. 1010 dock after the attack. The USS OGALALA is capsized to the right. Smoke billows from SHAW (top right USS HELENA is tied up to the left). (NPS: USAR collection)

Figure 2.13. Seaplane ramp at Ford Island where attack on Pearl Harbor Naval Base commenced. Masts of USS NEVADA can be seen in the background. (NPS: USAR collection)

Figure 2.14. Attack aftermath at Hickam Field. (NPS: USAR collection)

More important, American carriers and other ships not in port were now searching for him. At 1 o'clock the task force altered course and began its journey back to Japan. This decision was a major blunder that greatly minimized the long-term effects of the attack on the American war machine.

The USS ARIZONA

Operational History

The construction of the USS ARIZONA (BB39), named for the 48th state in the Union, began on March 16, 1914, when the keel was laid. After a year of intense labor, it was launched on June 19, 1915, as the second and last of the PENNSYLVANIA class battleship. The word Arizona comes from the Spanish-Indian term "Arizonac" meaning "few springs."

The launching was a grand affair, and Esther Ross, daughter of an influential pioneer citizen in Prescott, Arizona, was selected to christen the ship. The battleship's commissioning took place on October 16, 1916, under the command of Captain John D. McDonald.

The dimensions of the ship were quite impressive for the time. Its overall length was 608 feet (two American football fields long) with a beam of 97 feet 1 inch. It displaced 31,400 tons with a mean draft of 28 feet 10 inches. The ARIZONA's four shafts were driven by four paired Parsons turbines and 12 Babcock and Wilcox boilers that developed 33,375 horsepower, enabling a top speed of 21 knots. The designed complement was 55 officers and 860 men. The ARIZONA was well-armed for ships of its period. The original armament consisted of 12 14-inch 45-caliber guns; 22 5-inch 51-caliber guns; four 3-inch 50-caliber guns; and two 21-inch submerged torpedo tubes. It was protected by 18 inches of armor at its maximum thickness. The ARIZONA and its sister ship PENNSYLVANIA represented a modest improvement of the previous NEVADA-class battleships: "length and displacement were somewhat increased and two additional 14-inch guns were shipped, the main armament now being arranged in four triple turrets . . . " (Stern 1980:30). The significant change was concentrated in the firepower of the vessel: The ARIZONA's four turrets (labeled No. 1, 2, 3 and 4) each mounted three 14-inch naval guns.

On Nov. 16, 1916, the ARIZONA departed on its shakedown cruise and training off the Virginia Capes, Newport and Guantanamo Bay, Cuba. Two months later it returned to Norfolk, Virginia to conduct test-firing of its guns and torpedo-defense exercises. On December 24 it entered the New York Naval Shipyard for a post-shakedown overhaul, completed by April 3, 1917.

While in New York, the ARIZONA received orders to join Battleship Division 8 at Norfolk, which was to be its home port through World War I while it served as a gunnery training vessel. Due to the scarcity of fuel oil in the European theater, the ARIZONA (an oil burner) was deployed in American home waters to patrol the East Coast. When the Armistice was signed, it sailed for Portsmouth, England to operate with the British Grand Fleet.

A month later the new battleship was ordered to rendezvous with the transport GEORGE WASHINGTON that was carrying President Woodrow Wilson to the Paris Peace Conference. President Wilson carried a bold proposal intended to ensure a lasting world peace. In his outline for world cooperation, Wilson proposed 14 points to act as guidelines for a peace without victory and a new world body called the League of Nations. The ARIZONA would act as honor escort for the voyage to arrived in good order on December 13, 1918, but the failure of nations to grasp Wilson's ideals lead to World War II -- and the violent destruction of the honor escort USS ARIZONA -- 23 years later.

Later that month the ARIZONA returned to the United States carrying 238 doughboys home for Christmas. Celebrating the war's end, the ship passed in review in New York Harbor before Secretary of the Navy Josephus Daniels. After the parties and parades had faded, the ship continued to its home port of Norfolk.

In May 1919 a crisis arose that threatened American lives and property in Smyrna, Asia Minor. Having been placed on duty station in April at Brest, France, the ARIZONA was dispatched to respond to the grave situation. The ship disembarked Marines and sailors to protect the American consulate and bring aboard American citizens. When tensions eased, the ARIZONA was ordered home.

In June 1919 the ARIZONA entered New York Naval Shipyard for maintenance and remained there until January 1920, when it departed for fleet maneuvers in the Caribbean. That summer the ARIZONA became the flagship for Battleship Division 7, commanded by Rear Admiral Eberle, the future chief of naval operations.

The ARIZONA continued operations in the Caribbean Sea throughout the winter, and during that period made its first passage through the Panama Canal. The ship returned to Norfolk from Cuba on April 27, 1921 and was overhauled in the New York Navy Yard. That summer the ARIZONA participated in experimental bombing exercises of Navy seaplanes on a captured German U-boat, the first in a series of joint Army-Navy experiments conducted during June and July of 1921 to measure the effectiveness of air attack.

On July 1, 1921 the ARIZONA was honored as the flagship for three-star Vice Admiral John D. McDonald. With the flag came the title of flagship of the Battle Force, U.S. Atlantic Fleet. In August the flag was transferred to the USS WYOMING and the ARIZONA received a new admiral, John S. McKean, commander of Battleship Division 7.

In September of 1921 the ARIZONA was transferred to Pacific waters. At San Pedro, California, it underwent another change of command, when Rear Admiral Charles Hughes became the new commander of Battleship Division 7.

For the next decade the ARIZONA served as flagship for Battleship Divisions 2, 3 and 4. A number of distinguished officers served aboard the vessel, particularly Rear Admirals William V. Pratt and Claude C. Bloch. During this period the ship sailed twice to Hawaii to participate in fleet maneuvers and practice amphibious landings of Marines.

In February 1929 the ARIZONA passed through the Panama Canal for fleet maneuvers in the Caribbean. On May 1 the battleship returned to Norfolk in preparation for modernization overhaul. On May 4, 1929 it entered the yard at Norfolk for that purpose and was placed in reduced commission until July 1929. During this modernization the ARIZONA received a massive facelift. First to go were the traditional cage masts that were replaced fore and aft by tripod types. New 5-inch antiaircraft guns replaced the outdated 3-inch mounts. New armor was added below the upper decks to guard against the fall of shot by high-angle gunfire and bombs dropped by aircraft. Extra compartments called "blisters" were added to the outer hull to increase the ship's protection against torpedo attack. In an effort to offset the additional weight, a brand-new power plant consisting of modern boilers and turbines was installed to allow it to maintain normal fleet speed. The engines were upgraded

Figure 2.15. Launching of the USS ARIZONA from Brooklyn Navy Yard on June 19, 1915. (NPS: USAR collection)

Figure 2.16. Tugs control the ARIZONA after sliding off the ways (1915). (NPS: USAR collection)

Figure 2.17. The USS ARIZONA heads down the East River on its way to sea trials (1918). (NPS: USAR collection)

Figure 2.18. The USS ARIZONA after major modifications (1930s). (NPS: USAR collection)

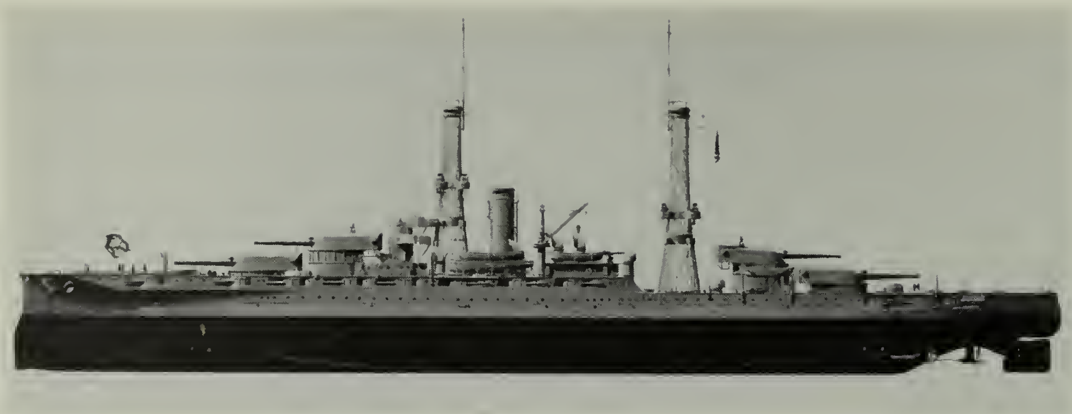


Figure 2.19. The USS ARIZONA before bird-cage masts were removed in modifications. (NPS: USAR collection)

Figure 2.20. The USS ARIZONA after major modifications. Note masts modernized and no torpedo tubes. (NPS: USAR collection)

Figure 2.21. The USS ARIZONA at Puget Sound Navy Yard in January 1941. This is the last known photograph before attack. (NPS: USAR collection)

with new geared units, and the original boilers were replaced with six Bureau Express three-drum boilers. The ARIZONA's fuel capacity was increased from 2,332 to 4,630 tons of oil. On March 1, 1931 modernization was completed, and the ARIZONA was placed in full commission once again.

One of the more significant events in the ship's history took place on March 19, 1931 when the ARIZONA embarked President Herbert Hoover and his party for a 10-day inspection cruise to Puerto Rico and St. Thomas in the Virgin Islands, then transported the President to Hampton Roads at the end of the month. The ARIZONA left Norfolk for the last time on August 1, 1931 and remained in the Pacific for the rest of its operational life.

Rear Admiral Chester Nimitz hoisted his flag as commander of Battleship Division 1 on September 17, 1938, with the ARIZONA serving as his flagship until May 1939. His successor, Rear Admiral Russell Willson, assumed command in San Pedro, California. As tensions grew in the Pacific, so did fleet responsibilities. On April 2, 1940 the ARIZONA moved into Hawaiian waters and was ordered up the coast to be overhauled at Puget Sound Naval Shipyard in Washington. The work was completed by January 23, 1941. At that time Rear Admiral Isaac Kidd relieved Rear Admiral Willson and took command of Battleship Division 1.

The ARIZONA returned to Hawaii in February 1941 and trained in those waters for four months. The last voyage to the West Coast occurred in June, and in early July the battleship returned to Pearl Harbor. For several months prior to the outbreak of the Pacific War, the ARIZONA's crew underwent intensive battle-readiness drills that often included mock air attacks from the carrier ENTERPRISE. The battleship entered drydock No. 1 on October 27, 1941 for minor adjustments and repairs.

Soon after the ARIZONA rejoined the fleet. The ship's exact movements for the month before the Pearl Harbor attack are vague, as the ship's log was lost in the sinking. The ARIZONA entered Pearl Harbor on December 6, 1941 and moored on the east side of Ford Island. Later that day the USS VESTAL (AR-4) pulled alongside to ready the vessel for repair work scheduled for the following Monday. At 10:00 that morning, Admiral Kidd came aboard the VESTAL for a 15-minute official call. Later, Cassin Young, the captain of the repair ship, boarded the ARIZONA to discuss the ship's pending repairs with the battleship's chief engineer.

Many of the ship's crew had liberty that Saturday. Some of the married men had wives on the island and received weekend passes. Nearly 50 crew members were shoreside at the time of the attack. However, a majority of the men had returned to the ship by midnight. Eight hours later the ARIZONA would be lying on the bottom of Pearl Harbor with the bodies of most of those men.

The Day of the Attack

The USS ARIZONA's configuration had changed very little since its 1931 modernization. However, in April 1939 and January 1941 alterations had been done to ready the vessel for war.

In that effort, an exposed pair of 5-inch, 51-caliber guns was removed so that new 1.1-inch quadruple machine-gun mounts could be installed on the superstructure deck abreast of the conning tower. Another set of the 1.1-inch mounts was also to be installed on the quarterdeck between the mainmast and gun turret No. 3. Foundations, ballistic shields, ammunition hoists, and ready-service lockers were installed. At the time of the attack, those areas were vacant of any armament -- the guns had been scheduled for installation in early 1942.

A variety of 50-caliber machine guns was installed to increase antiaircraft fire power. It was quite common to relocate such weapons from time to time to increase their arc of fire. Originally four were placed on the main platforms of each mast. In 1939 search lights carried on the funnel were removed, and two machine guns from the mainmast replaced them. In January 1941 at Puget Sound the vessel was fitted with a "birdbath" platform atop the mainmast director tower. The "birdbath" was filled with four 50-caliber guns, two from the foremast and two from the mainmast. Leaving two guns on the foremast platform and two on the funnel platform, searchlights were placed on the former gun platform of the mainmast. Splinter shields were mounted on the superstructure deck to protect the crews manning the eight 5-inch, 25-caliber guns located there.

Coupled with increased antiaircraft fire power was the installation of new Mark 28 antiaircraft directors that were supposed to increase the firing efficiency for the 5-inch 25-caliber guns. The location of the directors was on the range-finder platform level of the bridge. Here adequate support of the superstructure deck could be found via their heavy wiring tubes. This site afforded sufficient sky arc coverage for the directors' use. Early in 1942 the ARIZONA was scheduled to receive fire control and air search radar equipment. At the time of its loss, most of the structural modifications had been accomplished.

The ARIZONA was painted in a two-tone gray paint scheme commonly referred to as Measure 14, consisting of an ocean gray (dark) on all hull and superstructure masses. Haze gray (light) was applied to the masts, yards and towers above the level of the superstructure masses. This paint scheme was meant to break up the general outline of the ship at a distance. The hull and superstructure were meant to blend with the sea, the upper works with the sky. It obviously had no value to vessels in port. A majority of the Pacific Fleet was painted in that manner. The exact date of the order that authorized the Measure 14 scheme is not known, however, a recent discovery of a photograph of the USS UTAH showed this paint scheme being applied in October 1941.

One other note on the ARIZONA's final appearance: Morning canvas sun tarpaulins or awnings stretched above the main deck from the bow to the muzzles of gun turret No. 1. Awnings graced the quarterdeck from the break in the deck to the barbette of gun turret No. 3. Farther down the quarterdeck, awnings stretched from the gun muzzles of gun No. 4 to the stern. Most of the canvas was destroyed by the ensuing fire that engulfed the ship following the massive magazine explosion.

Battle Damage

At the time of the attack, the ARIZONA was moored at berth F-7, with the repair ship VESTAL moored alongside. The vessel suffered hits from several bombs and was strafed and then about 8:10 a.m. the battleship took a death blow. Petty Officer Noburo Kanai, in a high-altitude bomber, had earned the title of crack bombardier while training for the mission. Kanai was credited with dropping the bomb that blew up the ARIZONA (Prange 1981:513). The 1,760-lb. projectile hurtled through the air, reportedly striking near turret No. 2 and penetrating deep into the battleship's innards before exploding near the forward magazine. In a tremendous blast, the ARIZONA blew up.

Figure 2.22. Aftermath: December 1941, the USS ARIZONA from port bow looking aft. (NPS: USAR collection)

Figure 2.23. Aftermath: The USS ARIZONA midships area near boat cranes February 17, 1942. Note V for victory placed on splinter shield (center). (NPS: USAR collection)

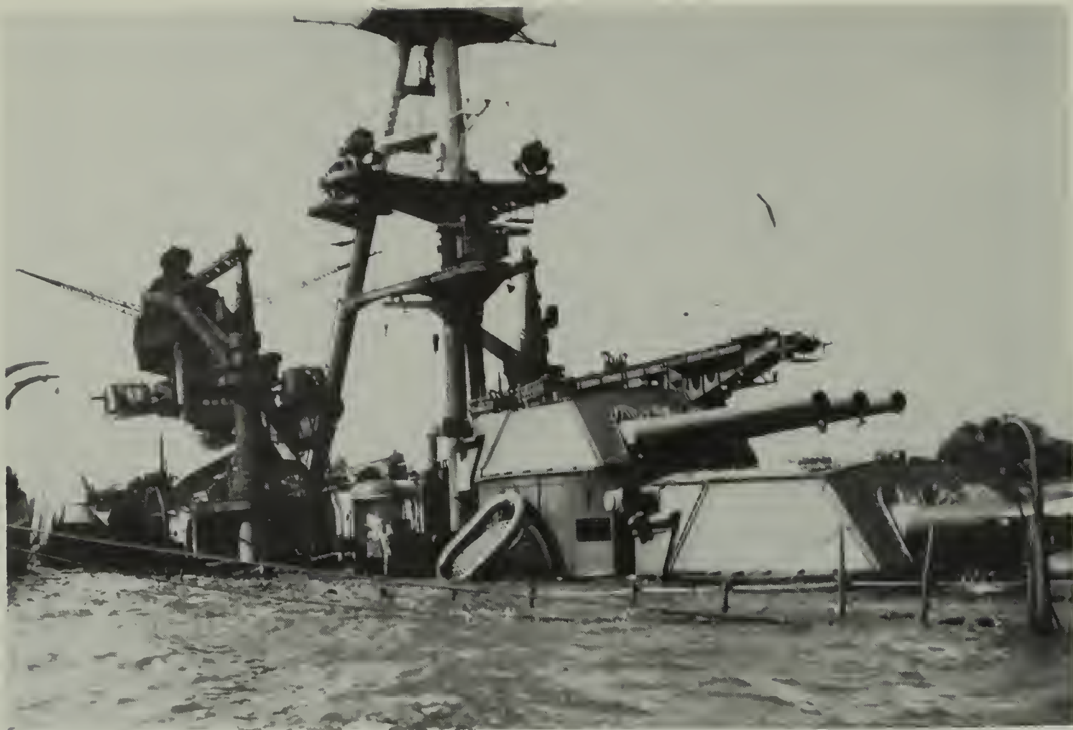


Figure 2.24. The USS ARIZONA from port stern looking forward. (NPS: USAR collection)

Figure 2.25. USS Arizona from starboard stern looking forward. (NPS: USAR collection)

Figure 2.26. Forward mast being removed from USS ARIZONA in May 1942. (NPS: USAR collection)

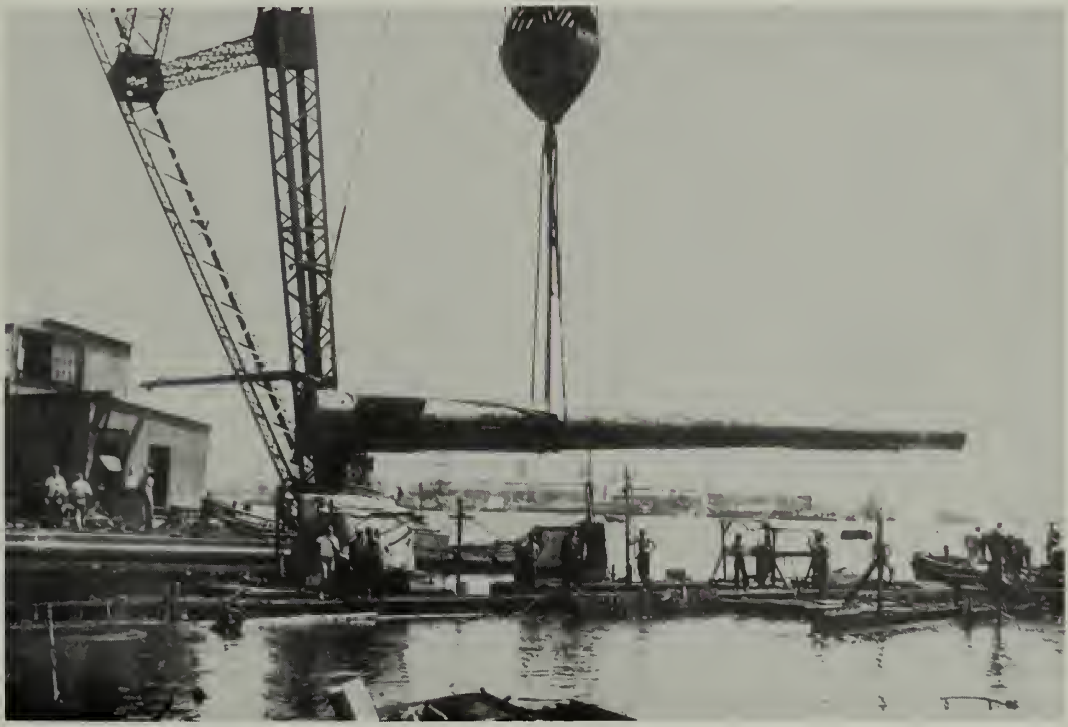


Figure 2.27. One of the 14-inch gun tubes being removed from USS ARIZONA August 5, 1943. (NPS: USAR collection)

In an instant, most of the men aboard were killed, including Rear Admiral I.C. Kidd and Captain F. Van Valkenburgh, both posthumously awarded the Medal of Honor. The blast from the ARIZONA blew men off the decks of surrounding ships and threw tons of debris, including parts of bodies, all over the harbor. Survivors of the attack also claimed that the ARIZONA was hit by one or possibly two torpedoes. The fury of the attack continued unabated, with the ARIZONA reportedly receiving eight bomb hits as it sank. Abandoned at 10:32 a.m., the ship's burning superstructure and canted masts loomed through the smoke that blanketed the harbor.

The ARIZONA received the most serious battle damage of the ships attacked on December 1941. The resultant explosion of ammunition and fuel demolished the forward section of the vessel, which collapsed inside the hull, and killed most of the ship's complement. Six days after the attack, the senior surviving officer from the ARIZONA forwarded the ship's action report to CINCPAC Admiral Kimmel and noted: "The USS ARIZONA is a total loss except the following is believed salvageable: fifty-caliber machine guns in maintop, searchlights on after searchlight platform, the low catapult on quarterdeck and the guns of numbers 3 and 4 turrets" (Memorandum, Commanding Officer, USS ARIZONA to CINCPAC, Pearl Harbor, T.H., December 13, 1941. Copy on file at the USS Arizona Memorial).

Salvage

Of all the ships lost or damaged at Pearl Harbor, the USS ARIZONA offered the most pathetic sight. Despite the crumpled superstructure and main decks awash, divers began exploring the wreckage of the ship within a week.

It was soon discovered that the after part of the ship from the break in the deck to the stern was relatively intact. Removal of safes, valuables and documents of a sensitive nature had begun by early 1942.

Assessment dives continued to evaluate the feasibility of raising the ARIZONA. Salvage officers initially considered building a cofferdam around the vessel's perimeter, thus sealing the ship off from the harbor to allow the pumping of water from interior spaces. Examination of the harbor's coral bottom concluded that it was too porous and would not allow this process.

Throughout 1942 and 1943, examination dives continued inside and outside the ship. Meanwhile, ordnance divers began to remove ammunition and projectiles in May 1942. Eventually guns, machinery and other equipment were removed for use on other ships or stations.

The divers found the interior of the ARIZONA had been severely damaged by the explosion of the forward magazines. Evidence of its power had shown that the explosion had vented through the deck forward of turret No. 1 causing a separation of the bow and the rest of the ship. Divers found further that the sides of the bow had been blown outward almost to a horizontal position. Closer examination of the exterior hull was assisted by jetting away mud with high pressure hoses. When divers attempted to move forward into the interior of the vessel, they found that the main and second decks were blocked with wreckage forward of frame 76. The furthest divers could move toward the bow of the ship was on the third deck to frame 66, where the second deck sloped into the third deck. Hatches that had once led to the interior of the ship from various decks were now twisted and distorted. Captain Homer Wallin and his staff found that gun turrets No. 1 and 2, the conning tower and uptakes had fallen 20-28 feet indicating a collapse of the supporting structure.

On May 5, 1942, the toppled foremast of the ARIZONA was cut away and removed. The mainmast was taken away by August 23. Other features removed were the stern aircraft crane (December 23) and the conning tower (December 30).

The Navy decided that the Army would receive gun turrets No. 3 and 4 for use as coastal defense guns. Two sites were selected: one at Mokapu Head (Kaneohe) known as Battery Pennsylvania and the second at an area known today as Electric Hill (HEI generating plant) on the western shore of Oahu, up the slopes of the Wianae Mountains. Only Battery Pennsylvania was completed. A test firing took place four days before the surrender of Japan. Today both sites are abandoned; the guns were removed and cut up for scrap shortly after the war ended.

Despite the work done to remove all useful materials from the ARIZONA, it was apparent the ship itself was lost. A memorandum from the Commandant of the Navy Yard to Washington in June 1942, suggested abandonment of salvage work on the ARIZONA because it was a "task of great magnitude entailing the diversion of large numbers of men and equipment from other work." In his mind, as well as others the conviction had formed that ARIZONA would never fight again. On December l, 1942, the vessel was struck from the books of commissioned ships. By October 1943, the last salvage work was completed. The ship had been stripped down to the main deck, none of the graceful superstructure remained.

One question still haunts visitors to the Arizona Memorial even to this day. Why were the dead not removed? Initially, about 105 bodies were removed but because the ship was never raised, the remainder could not. The priority at that time was salvage of ships that could be repaired -- the ARIZONA was not in that category. As a result, the bodies deteriorated to the point of not being identifiable. Even as late as 1947, requests were made in regard to removal of the dead, but rejected. They are considered buried at sea by the US Navy.

In 1961 the USS ARIZONA was altered once more. In order to place the present memorial over the ship, a section of the boat deck that rested over the galley amidships was cut away. Initially this had been the area of a flag and platform for ceremonies and visits to the site from 1950-1960. This portion of the ARIZONA was removed to Waipio Point where it remains today.

The USS UTAH

Construction and Operational History

The UTAH has been almost forgotten. Seldom honored by public visits, it rests in the waters of Pearl Harbor as a distant memory of America's most remembered day, a sad epitaph for a fine battleship.

The construction of the USS UTAH was part of an early 20th-century arms race, at the time when global military supremacy was determined by control of the seas. The rise of the battleship as the super weapon of the world's navies had roots in the era of wooden vessels but commenced in earnest with the combat between the USS MONITOR and the CSS VIRGINIA (MERRIMACK) during the American Civil War, though the first true American "battleship" did not slide from the ways until 1895. The first battleships, of which the famous USS MAINE was one of four, were key in the United States' victory in the Spanish-American War and were in turn

Figure 2.28. Rotating portion of turret no. 3 being removed. View from rear. (NPS: USAR collection)

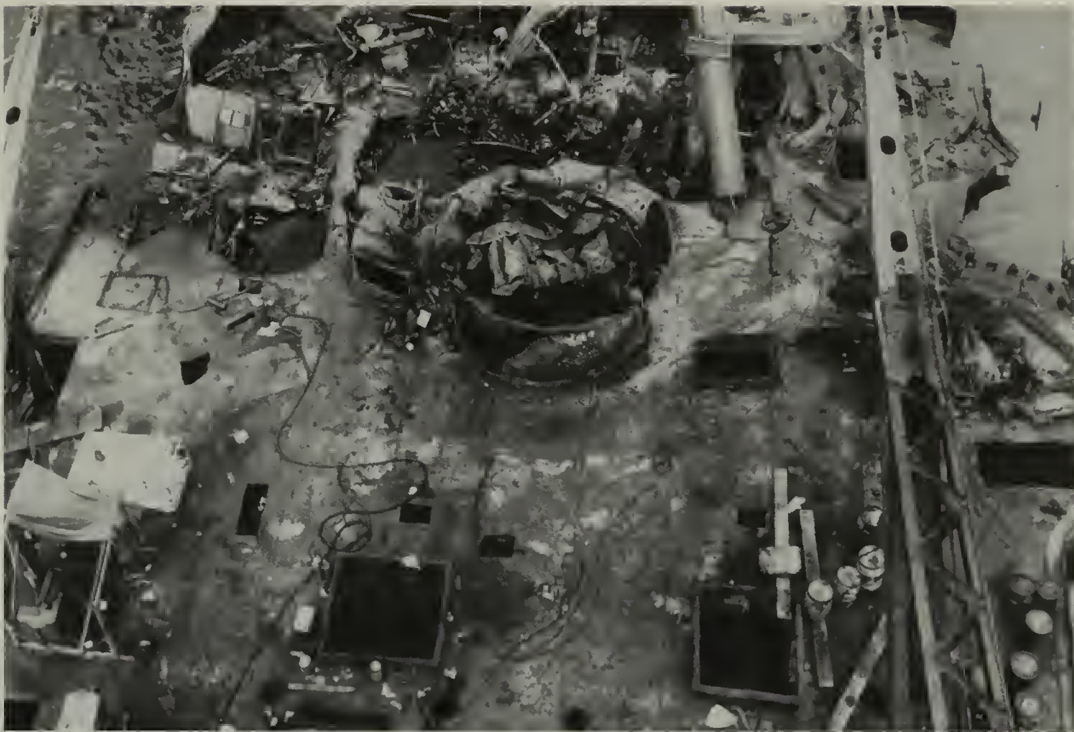


Figure 2.29. View looking forward on deck when superstructure is being removed. (NPS: USAR collection)

Figure 2.30. Salvage team removing air mask and safety belt after work in partially unwatered after magazines. (NPS: USAR collection)

Figure 2.31. Salvage operations, team about to enter pressure lock. (NPS: USAR collection)

Figure 2.32. Salvaging powder bags from the USS ARIZONA. (NPS: USAR collection)

Figure 2.33. The USS UTAH as battleship before conversion. (NPS: USAR collection)

Figure 2.34. The USS UTAH in heavy seas when still a battleship (courtesy Norm Harp).

followed by other vessels, many built during the presidency of Theodore Roosevelt, whose 16-vessel "Great White Fleet" circled the globe in a show of American naval might. Despite the great number of American battleships, new developments in the years just preceding the First World War rendered them obsolete. These developments -- steam turbines, multiple turrets mounting increasingly large-bore rifled guns (from 10- to 12- to 14-inches) and improvements in armor -- made the battleship an even more formidable weapon and the focus of naval arms races.

The United States and other naval powers were alarmed by British plans to construct a new battleship, HMS DREADNOUGHT, that would embody the new developments with 10 12-inch guns and steam turbines driving the ship at 22 knots. Even as the last of Roosevelt's Great White Fleet slid from the ways and embarked on a world tour, plans for new American "dreadnoughts" were on the drawing boards. Named for the first vessel of the new class, the USS FLORIDA, these new battleships mounted multiple 12-inch guns, and with turbines (and unfortunately in some cases with old-fashioned reciprocating steam engines) they proved a match for the European dreadnoughts; in concert with the British they showed their mettle in the First World War (Stern 1980:4).

Second of the FLORIDA class, the USS UTAH was laid down on March 6, 1909, at the Camden, New Jersey yard of the New York Shipbuilding Co. Completed nine months later, the UTAH was launched on December 23, 1909. Work to prepare the ship for sea took longer, and the UTAH was not placed in commission until 1911. Assuming command of the ship was Captain William Benson. The UTAH statistics were impressive for the "Dreadnought era" -- 21,825 tons that drew approximately 28 feet. Top speed was estimated at 20 knots. The crew consisted of 60 officers and 941 men. Fire power was measured by five gun turrets, armed with two 12-inch guns. Supplementing the main armament were 16 5-inch, 51-caliber guns and two 21-inch submerged torpedo tubes. Armor 12 inches thick surrounded the vital areas of the vessel. After a shakedown cruise south along the coast, into the Gulf and then the Caribbean, the UTAH was assigned to the Atlantic Fleet in March 1912. For the next two years the battleship was assigned to regular duties in the Atlantic Fleet: drilling and engaging in training cruises.

In 1914 the UTAH played an important role in the American landings at Veracruz, Mexico. Mexico, torn by civil war and revolution, was the scene of considerable American intervention, much of it centered at Veracruz and Brig. Gen. John J. Pershing's forays into northern Mexico. The UTAH was deployed twice at Veracruz, first from February to April 1914, when it anchored off Veracruz and transferred refugees to nearby Tampico, and again in late April to June 1914 when it joined other American ships in an attempt to contravene the landing of arms shipped from Germany to Mexican president Victoriano Huerta, who had succeeded the assassinated legal president, Francisco I. Madero. President Woodrow Wilson, eager to support Madero backers and anti-Huerta revolutionaries as part of his international campaign for human rights, and seeking the means to stabilize war-torn neighboring Mexico, sent in troops. Marines and sailors landed from the U.S. Naval vessels, including UTAH, took Veracruz on April 21, 1914, seized the customhouse and prevented the landing of the arms. In the action, seven members of the UTAH's crew distinguished themselves and received Medals of Honor. Considerable Mexican casualties embarrassed the United States and led to an American withdrawal, but the action was one of a series of maneuvers that led to Huerta's downfall and the installation of a new government (Mooney 1982:421-422).

Until the outbreak of World War I, the UTAH continued with fleet battle practices and maneuvers in the Atlantic and Caribbean. Once the war was underway, the UTAH became a training ship for gunnery and engineering for hundreds of new recruits.

On September 10, 1918, new orders moved the UTAH to the theater of war. On that day, it arrived at Bantry Bay, Ireland, to become the flagship of Rear Admiral Thomas S. Rodgers, commander of Battleship Division Six. From Ireland the UTAH was directed to protect convoys and secure naval approaches to the British Isles.

The war ended that year. The UTAH was ordered to serve as honor escort for the transport GEORGE WASHINGTON that was carrying President Woodrow Wilson to the Versailles Peace Conference. Conspicuously present with the honor escort was the USS ARIZONA. President Wilson arrived in Brest, France, on December 13. The following day the UTAH departed for home and overhaul in the Boston Navy Yard.

For the next 12 years the UTAH served with distinction in the Atlantic Fleet. It sailed to several South American ports to "show the flag" and to serve as transport for diplomatic and goodwill missions. In 1924-1925 it earned the Navy Battle Efficiency Award "E" for outstanding gunnery. Summers of those years saw many a midshipman from the Naval Academy scramble around its decks as the ship served with the Midshipman Practice Squadron.

The London Naval Conference set limits for naval armaments, particularly the number of battleships that a nation could have in its naval arsenal. The UTAH was one of those condemned as a battleship and was designated to be removed from service in order to comply with the London treaty. In 1934 the ship was saved at the last moment from demolition when Navy officials decided to remove the armament and convert the vessel to an experimental mobile target ship at the Norfolk Navy yard.

On July 1, 1931, the UTAH was redesignated a miscellaneous auxiliary ship, and the hull was reclassified from BB-31 to AG-16. Conversion took nearly a year, but as a result the UTAH became one of the most sophisticated technical marvels of the period. Certainly the installation of the radio-controlled steering and steaming apparatus bears witness to the scientific advances of the 1930s. The mechanism allowed the UTAH to be controlled from another ship or aircraft. The ship could steam at varying rates of speed, alter course and lay smoke screens. It could maneuver as a ship would during battle. All this was accomplished by electric motors that could open and close throttle valves, position the steering gear and regulate the supply of oil to the boilers in order to generate smoke for laying down screens. This "robot" man-of-war was steadied by a Sperry "metal mike" or gyro pilot in order to keep the ship on course.

By April 1, 1932, the UTAH was ready and placed in full commission by Commander Randall Jacobs. Six days later it left Norfolk, Virginia to begin the shakedown cruise to train the shipboard cruise engineers and to test the radio control equipment under trial conditions. Although the UTAH could operate without the touch of human hands, it did have to be monitored. The maximum time for unassisted operations was four hours.

In the past it had taken 500 men, including officers and seamen, to operate the vessel. The UTAH broke new ground in the field of remote control, and that groundwork was used for space exploration and guided missiles more than a generation later.

The UTAH left the waters of the Atlantic in June 9, 1932, as it set sail for San Pedro, California via the Panama Canal. Twenty-one days later it joined Training Squadron One, U.S. Pacific Fleet.

During this period the UTAH realized its full potential as a target ship. In retrospect, a common misunderstanding about the UTAH is its role and appearance. During those years the ship's role was to duplicate conditions of battle maneuvering that could test the skills of those who were being trained to attack from air or sea. Air attack on the UTAH was not without hazards during remote and manual operation. It has been estimated that dive bombers scored hits 15 percent of the time and high-altitude horizontal bombers about 5 percent. The practice bombs were inert but struck the ship with such velocity and force that it could penetrate the steel decks. In an effort to prevent this damage from occurring, huge wooden timbers were placed on the ship's deck. Needless to say, when the air attack took place, the crew exercised great caution. A majority of the crew found protection within the ship's armor. The spotters sought protection and visibility in the armored conning tower near the bridge.

When a bombing run was completed, a marking party came on deck to mark and score hits. However, this routine nearly ended in tragedy when a number of sailors were standing on the deck and a group of planes appeared suddenly out the clouds and let missiles fly. Bad aim and quick feet prevented wounding or death to members of the crew.

Surface vessels such as battleships, cruisers and destroyers found the UTAH useful in long-range firing exercises. Although they never fired directly on the UTAH, they did direct their aim at the target rafts that the ship towed. This training allowed surface warships to maneuver in battle conditions that honed surface-firing skills. Submarines found the UTAH excellent training, because the ship responded like high-speed prey.

On April 30, 1935, the UTAH joined other elements of the Pacific Fleet for a cruise to the Hawaiian Islands. On the voyage to Pearl Harbor, the ship was readied for a new training task -- amphibious operations at Hilo Bay on the island of Hawaii, where it debarked 223 officers and men from the fleet's Marine contingent, along with full equipment and armament.

The UTAH was changed over in August 1935 to an antiaircraft training ship for the Pacific Fleet, a status ultimately more important than the category of mobile target ship. Fleet officials established a machine-gunners'school that month, and trainees came aboard the UTAH from several cruisers and the aircraft carrier RANGER. The skill in particular of the RANGER's gunners was hailed by the Commander Aircraft Pacific Fleet Battle Force. Thus the UTAH embarked on a new phase of training that would occupy the remaining years of the ship's life until its demise in December 1941.

Notable among the experimental achievements was the development of a reliable fire-control system for 50-caliber machine guns for shipboard antiaircraft systems. This system would later be integrated in the use of the 1.1-inch antiaircraft gun. That same type of weapon was slated to be installed on board the ARIZONA in mid-December 1941.

In April 1940, the UTAH proceeded up the coast from San Pedro, California to Puget Sound for installation of a 5-inch 25-gun battery, considered by many as the best antiaircraft weapon in existence. From Washington the UTAH sailed for

Figure 2.35. The UTAH underway as bombing target ship in 1939. (NPS: USAR collection)

Figure 2.36. UTAH receiving new coat of camouflage paint shortly before attack. (NPS: USAR collection)

Hawaiian waters to conduct an advanced antiaircraft gunnery school. Trainees arrived aboard from the battleships WEST VIRGINIA, COLORADO, NEW MEXICO, and OKLAHOMA and the cruisers NEW ORLEANS, PHOENIX, NASHVILLE, and PHILADELPHIA. For several weeks the crews practiced loading and controlling the 5-inch batteries, 50-caliber machine guns, and 1.1-inch guns.

After the training was completed, UTAH returned to the West Coast and eventually went back to Puget Sound Naval Shipyard. The UTAH entered the docks on May 31, 1941. For nearly three months the ship underwent massive changes to the shipboard training armament. Two turreted 5-inch 38-caliber guns were placed on top of the original 12-inch gun turrets, Nos. 4 and 5. An advanced gun director was secured to the top of gun turret No. 5. Amidships were placed two 5-inch 38-caliber guns on the port side and two on the starboard side. In order to fill the antiaircraft armament gap between the 5-inch batteries and 50-caliber machine guns, the Navy installed experimental, advanced 20mm automatic antiaircraft weapons. The testing and the proficiency with these guns enabled the Pacific Fleet to prepare for a war that appeared to loom even closer as the summer of 1941 wore on.

Before leaving Puget Sound, the UTAH war colors were applied in the form of Measure 14 paint scheme. Dark sea gray was painted on the hull and lower superstructure and light haze gray to the upper main tops. The UTAH eventually made its way along the West Coast to San Pedro. It was never to return to those familiar waters. It set sail for the last time for Hawaii on September 14, 1941. For six weeks it held an advanced antiaircraft firing practice in Hawaiian waters. For the weekend of December 6-7, the UTAH returned to Pearl Harbor and moored at berth F-11 on the west side of Ford Island.

UTAH: Day of the Attack

One of the first vessels attacked by the Japanese was the UTAH. Commanders Genda and Fuchida, planners of the attack, had ordered their pilots to ignore the training ship, which as a non-combat ship was not worthy of attack, but eager pilots dropped two torpedoes on the UTAH and the nearby light cruiser RALEIGH. One torpedo slammed into the UTAH's port side at 8:01 a.m. as the crew raised the flag on the fantail. Some minutes later a second hit the same area. This action infuriated Lt. Heita Matsamura, flight commander for the torpedo bombers from the carrier HIRYU, who had "specifically instructed his men to avoid UTAH." Nonetheless pilots from the SORYU attacked, and following the first hit, Lt. Tamotsu Nakajima, "young and inexperienced . . . followed suit." (Prange 1981).

Water began to fill the ship rapidly, and it listed 15 degrees. The senior officer aboard, Lt. Commander S.S. Isquith, realized that the UTAH was sinking and gave the order, "All hands on deck and all engine room and fire room, radio and dynamo watch to lay up on deck and release all prisoners." The crew was ordered to the starboard side of the vessel to escape the danger of loose timbers pinning men down or striking them. These timbers had been used in previous weeks to cushion the deck from practice bombs dropped by planes from the ENTERPRISE. By 8:05 the list had increased to 40 degrees. The ship was lost. "Abandon Ship over the starboard side" was shouted over the din. As the men scrambled for safety, the increased list caused the timbers to loosen and slide in the water, crushing the men below. At about 8:12 the UTAH capsized after moor-

Figure 2.37. The UTAH as target ship with timbers protecting deck from practice bombs. (NPS: USAR collection)

ing lines snapped. The ship's boats rushed in and picked up men in the water. Constant strafing made the job hazardous, and many men sought shelter by swimming to the side of the mooring quay. The wounded and injured were treated along the shoreline or sent to the dispensary at the Naval Air Station at Ford Island. As survivors continued to struggle ashore, many sought protection in trenches dug by the Public Works Project. While the crew huddled for protection, loud banging was heard coming from the ship's hull. A party of UTAH men volunteered to investigate while the attack was still underway. They eventually climbed onto the upturned hull and listened intently. Machinist Mate S.S. Szmanski and two seaman were located by the tapping from void space V-98. The rescue party went immediately to work to free the trapped personnel. Szmanski obtained a cutting torch from the USS RALEIGH and a hole was cut, allowing F2C John Vaessen to be rescued. For his action that day, Szmanski was awarded the Navy Cross.

Thirty officers and 431 men survived the loss of the ship. At best estimates, six officers and 52 enlisted men were lost, some trapped aboard ship, others cut down by strafing aircraft. One of the many examples of heroism that day was displayed by Chief Watertender Peter Tomich. As the ship began to list, Tomich remained at his station so that others could escape. He enabled the men in his division of engineering to flee the sinking ship, and in doing so lost his own life.

The UTAH was declared to be temporarily out of service -- "in ordinary" -- on December 29, while salvage teams under Captain Wallin tried to determine if it could be salvaged.

Salvage

The immediate problem faced by the salvage teams was to determine the extent of damage and whether the ship could be righted. In November 1942, a series of surveys was completed that included establishment of a mud line from bow to stern. Early thinking believed that an air bubble could be used to float the hull to drydock. Closer examination determined that the UTAH simply could not hold enough compressed air to make such a trip.

Another approach was considered. The conditions that faced the UTAH were similar to those in the righting of the OKLAHOMA. Captain Wallin and his staff decided that the OKLAHOMA's method would accomplish the task. In preparation, during the month of January 1943, workers removed ordnance material, painted frame marks on the hull, constructed a floating walkway to the F-11-N quay, installed a landing for boats, and drilled access holes to remove the ship's oil supply.

Like the OKLAHOMA, a series of 17 electric winches, cables and wooden struts was used to right the ship. Work on the UTAH proceeded slowly but effectively until early in 1944. As the ship began to roll back to an upright position, the vessel failed to grip the bottom. As the winches pulled, the vessel slid toward Ford Island. Immediately work stopped, and salvage engineers pondered the problem.

It was resolved that continued salvage would be costly for a ship that was not valuable in the war effort, so by March 1944 work stopped. The UTAH rested on its side at a 38-degree angle.

In 1956, a new effort to remove the UTAH was rekindled by the commandant of the Fourteenth Naval District, who felt that ESSEX-class carriers had insufficient space to initiate transfer of ammunition, special weapons and guided missile com-

Figure 2.38. The USS UTAH turned turtle after attack. (NPS: USAR collection)

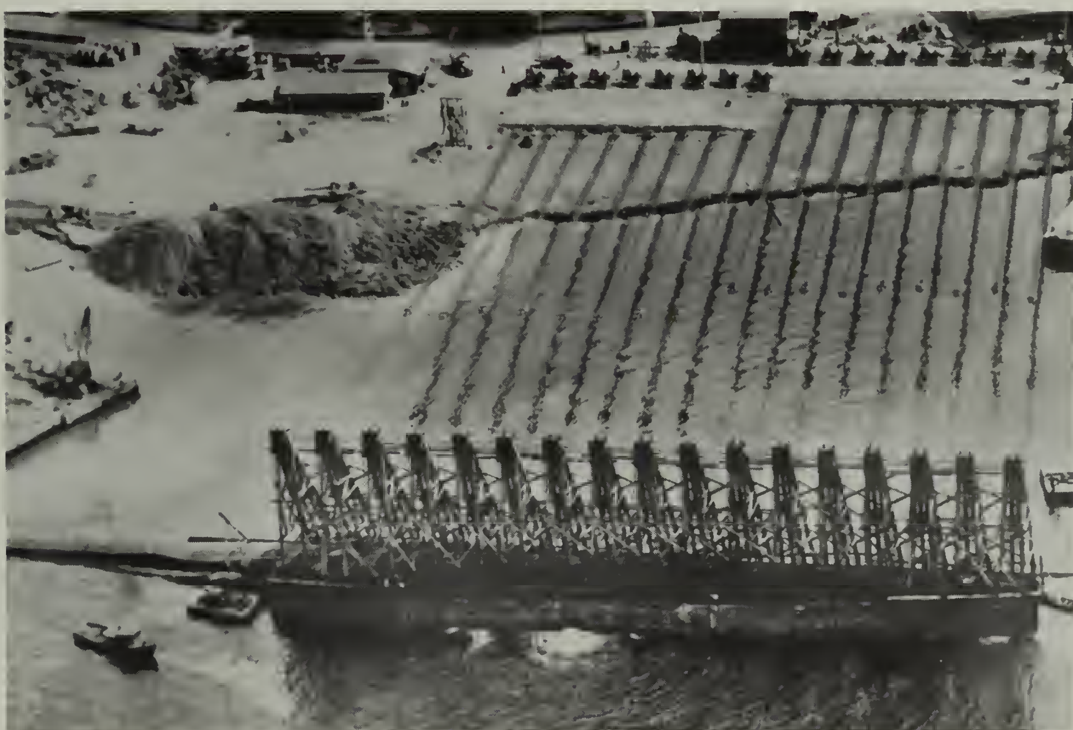


Figure 2.39. The UTAH salvage operations attempt to right the ship. (NPS: USAR collection)

ponents. Perhaps in an effort to make his case more solid, the commandant suggested that the UTAH obstructed navigation in the channel and should be removed. This was seconded by the Service Force, the fleet maintenance officer and the Pacific Fleet.

The cost for removal was estimated at $4,000,000, but soon a number of issues began to plague the commandant's effort. First, no funds were available. Second, the equipment used initially to right the vessel had been sold. Third, the project could take one and a half to two years.

Perhaps the most important factor leading to discontinuing the plan was raised by the Chief of Naval Operations: He simply stated that the vessel was the final resting place of 58 sailors and should not be disturbed.

Early in 1970 it was proposed by the shipmates and supporters from the state of Utah that a memorial be built to honor the dead. On May 27, 1972 Senator Moss of Utah, who had led the fight for approval and construction, dedicated the memorial.

The Legacy of the UTAH was ever-present in the struggle of the pacific. The training it had provided to the pilots, warships, subs and antiaircraft gunners enabled the Pacific Fleet to be an effective fighting force early on. The weapon testing system had allowed that fleet first-hand experience in working effectively. The ship had contributed significantly to the scientific testing of remote systems, gunnery training and aerial attack. In a larger sense, the UTAH helped prepare America for war.

Other Pearl Harbor Salvage Activities

Salvage of the ARIZONA and the UTAH have been discussed earlier in this chapter to clarify the processes that contributed to the formation of the archeological sites they have now become. As further background for the archeological survey (which included examination of the mooring key areas of Battleship Row), it is instructive to understand what transpired in the other major salvage efforts at specified sites.

The attack on Pearl Harbor left the Pacific Fleet in a state of chaos and impotence. Japan's goal had been achieved: The U.S. Navy was unable to oppose the Japanese invasion of Southwest Asia, the Philippines and islands of the South Pacific.

Twenty-one ships of the Pacific Fleet had been sunk or damaged. Of that number, eight battleships were casualties, five sunk and three damaged. The main battle line of the fleet was out of action.

Of growing concern was the location and intention of the Japanese navy. Fleet commanders at Pearl Harbor ordered their officers to assemble a priority list of ships that could be put back into service. This could then allow the fleet the opportunity to prepare for battle and form strategies.

Fortunately, the fleet had sunk in shallow water, a circumstance that made salvage operations feasible. On December 14, 1941, Commander James Steele began to direct salvage operations. On January 9 he was relieved by Captain Wallin, who formed a salvage organization consisting of Navy officers and civilian contractors, such as Mr. Matthew Dillingham, Pacific Bridge Company and Morrison-Knudson.

The civilian groups provided Wallin with the necessary tools and expertise to get the job done. In particular, the Pacific Bridge Co. recommended the use of underwater concrete to seal the holes of the ships in lieu of building sheet-steel cofferdams.

As salvage began, Wallin's first priority was recovery of antiaircraft guns and directors from the stricken ships. This armament and equipment were then used to

Figure 2.40. The UTAH partially righted during salvage operations. (NPS: USAR collection)

bolster the island's defenses as well as being provided to other ships. With the priorities for salvage set, work schedules around the clock were set in motion for the ships' crews and the Navy shipyard workers.

As he wrote about the salvage operation, there was "a dire shortage of pumping equipment, lumber and other materials . . . However, the spirit of the times was to do the best with what we had."

The hazards for such an operation were high. Poisonous gas and unexploded ordnance were ever-present dangers that could result in fire, explosion and death. Sticking to a priority list, Captain Wallin began work on the less damaged ships so they could return to service as soon as possible.

Vessels Damaged

The USS PENNSYLVANIA (Battleship)

The ship in drydock No. 1 had received minor damage during the attack. A 250kg bomb had damaged a 5-inch 51-caliber antiaircraft gun and then exploded two decks below. Another 5-inch gun had been knocked out temporarily. The ship had suffered fragmentation damage that had compromised splinter protection, the deck, electrical gear, water mains and structural steel.

In 13 days the damage was repaired and the 5-inch 51-caliber gun replaced by one from the USS WEST VIRGINIA.

The PENNSYLVANIA had been in drydock no. 1 on December 7 to align the shafts and propellers. That work was completed after the attack. On December 20 the ship was ready for sea duty.

The USS HONOLULU (Cruiser)

The ship was nearly hit by a 250kg bomb that passed through a pier and into the water, exploding 20 feet from the hull. The result was a buckling of the hull 5 to 6 feet deep, running over 40 feet in length. This resulted in the flooding of compartments and a magazine. On December 13, 1941, the USS PENNSYLVANIA left drydock No. 1, and the USS HONOLULU entered for permanent repair. All hull work was completed by January 2, 1942. The ship was then returned to the Yard for work on the superstructure, wiring and other repairs.

The USS TENNESSEE (Battleship)

The vessel was struck by two bombs, both 800kg projectiles that failed to detonate. One struck the center gun of turret No. 2 and the other pierced the roof of turret No. 3, rendering both turrets inoperable. The TENNESSEE's real tragedy was being pinned to the mooring quays by the sinking of the outboard ship USS WEST VIRGINIA. The vessel was freed on December 16, 1941, and moved to the Yard for minor repairs. The vessel was ready for fleet service by December 20, 1941.

The USS MARYLAND (Battleship)

The MARYLAND sustained minor damage from two bombs that struck the port side of the hull below the water line. This flooded several compartments but never threatened the ship. A caisson was placed around the damage to the hull and by December 20, 1941, the ship was ready for fleet service.

The USS HELENA (Cruiser)

The ship was struck by a torpedo that had passed under the USS OGLALA while tied up to 1010 dock. The explosion opened up the starboard side of the vessel below the armor belt and flooded engine rooms 1 and 2. Counter-flooding stabilized the vessel. The HELENA was the first to enter the recently completed drydock No. 2. On December 10, temporary repairs began and were completed 11 days later.

The ship set sail on half power for Mare Island Navy Yard, where permanent repairs were made.

The USS HELM (Destroyer)

The HELM escaped Pearl Harbor during the attack. As it cleared the harbor entrance, the destroyer patrolled the waters outside the harbor looking for submarines. At 9:15 a.m., a Val dive bomber dove on the HELM and delivered two 60kg bombs, one that hit 100 feet off the bow and the other within 30 feet to starboard abreast of frame 10. The near miss caused considerable damage. It was found later on January 15, 1942 while the ship was drydocked at the Yards Marine Railway that the keel had buckled, with shear lines running forward of bulkhead No. 14.

The HELM returned to sea in January and joined the fleet in San Diego, California.

The USS RALEIGH (Light Cruiser)

In the opening minutes of the attack, the ship was struck by a torpedo. The damage caused the flooding of two forward boiler rooms and the forward engine room. At 9:00 a.m. the RALEIGH was struck by a bomb that passed through three decks and out the side of the ship. The ship was in danger of sinking. Desperate measures were taken to jettison all topside weights and to counter-flood to correct a severe list. But despite these actions, the ship was slowly being lost. In desperation, salvage pontoons were brought along the port side and lashed to the ship to stabilize the list.

Most of the repairs after the attack were performed by the ship's crew and repair vessels at Pearl Harbor. On January 3 drydock No. 1 became available. Permanent repairs to the hull and bulkheads were completed at the yard by February 14, 1942.

The RALEIGH departed soon after for Mare Island Navy Yard on one engine. New engine parts and electrical parts were installed. The vessel rejoined the fleet on July 23, 1942.

The USS CURTISS (Seaplane Tender)

At 9:05 a.m. the CURTISS was struck by a Japanese plane that crashed into the forward crane and burned on the boat deck. Seven minutes later Japanese Val dive bombers began zeroing in on the ship. Three bombs were near misses that caused considerable damage. A fourth bomb struck the starboard side of the boat deck, crashed through three decks, and exploded on the main deck, resulting in serious damage. A majority of the damage was confined to fragmentation of piping, electric wires, steam lines, and structural alterations due to the explosions. Fires had swept certain areas of vessel resulting in predictable destruction.

For the most part, workers at the yard at Pearl repaired the vessel. The repairs took place in two stages, December 19 to 27 and April 26 to May 28, 1942. At that time, the vessel was restored to service.

The USS VESTAL (Repair Ship)

The VESTAL was moored outboard of the USS ARIZONA. At the time of the attack, the ship was struck by two bombs. The first struck the forecastle and crashed through several decks before exploding. Fortunately it detonated in the metal storage room, which deadened the impact. The second bomb passed through the ship before exploding under the stern.

What complicated matters further was the explosion of the ARIZONA and the intense flames and heat of the fires. Aided by two tugs, the VESTAL withdrew from Battleship Row and eventually beached on Aiea Shoals to prevent sinking.

Being a repair ship, the crew was more than qualified to begin repairs on their vessel. As soon as drydock facilities were available, the ship entered for permanent repairs. By February 18, 1942, the VESTAL was back to the business of repair for the fleet.

Vessels Sunk

It was one thing to repair damaged ships, but it was quite another to raise a sunken vessel. "There was a feeling of depression throughout the Pearl Harbor area," wrote Captain Wallin, "when it was seen and firmly believed that none of the ships sunk at Pearl Harbor would ever fight again."

The USS SHAW (Destroyer)

The USS SHAW, while in floating drydock No. 2, may have been struck by errant bombs probably intended for the escaping USS NEVADA. The first two projectiles struck the vessel near the forecastle just aft of gun No. 1. This caused an explosion of the ship's forward platform deck, severing the bow forward of the bridge. A third bomb passed through the bridge, rupturing the fuel tanks and starting a fuel oil fire that caused the forward magazines to explode.

Within minutes, the floating drydock sank, taking the forward section of the ship with it. The remainder of the ship remained afloat. It was reported at the time that the ship was a total loss.

However, it was decided that the forward section be replaced by a fabricated bow when the ship was docked on the Yard's Marine Railway on December 19, 1941. The vessel was moved once more to the restored floating drydock No. 2, where a bridge and a temporary mast and ship's control station were installed. Trials were held to test its seaworthiness, and the SHAW departed for Mare Island on February 9, 1942, for permanent repairs.

Floating Drydock No. 2

The floating drydock was occupied by the USS SHAW during the attack. Japanese bombs began dropping on and near the dock around 8:50 a.m. It is estimated that five bombs from Val dive bombers recorded near misses or direct hits, causing 155 holes in the vessel and, finally, its sinking.

Salvage and repair began within weeks, and the dock was raised on January 9, 1942. Hasty patchwork made it ready for its first customer, the USS SHAW. Permanent repairs were completed by May 15, 1942.

SOTOYOMO (Tug)

This vessel was forward of the USS SHAW within the confines of the floating drydock. Because of the explosions and fires that racked the SHAW, the SOTOYOMO sank. It was expected that the tug was a total loss, but careful salvage and ship-raising techniques prevailed. In the summer of 1942, the SOTOYOMO was restored to full-time duty at Pearl Harbor.

The USS DOWNES (Destroyer), the USS CASSIN (Destroyer)

The CASSIN was occupying drydock No. 1 with the DOWNES to its starboard side and the flagship of the Pacific Fleet, the PENNSYLVANIA, aft. As the attack progressed, the drydock was bracketed by several bomb hits. As a result of fires, fragmentation and flooding of the drydock, the vessel was lost.

The damage was so extensive that the two vessels were considered beyond repair. On further examination, it was found that the main propulsive machinery was sound.

The newly named Pearl Harbor Repair and Salvage Unit went to work immediately to restore the vessel's floatability. On December 12, the PENNSYLVANIA was moved, and the drydock was drained to allow the crews to reblock the destroyers. By February 18, 1942, the ships were removed from drydock.

Both ships were sent to the Mare Island Navy Yard in California to be reconstructed. The DOWNES reported to the fleet for duty in November 1943 and the CASSIN in February 1944.

The USS NEVADA (Battleship)

Originally the NEVADA was the end vessel of Battleship Row. While the attack was underway, the battleship attempted to sortie from the harbor around 8:40 a.m. Its gallant dash for safety ended at Hospital Point with the beaching of the ship to prevent it from sinking in the harbor channel.

An assessment of the NEVADA's damage after the attack found:

1. A torpedo had struck the ship at 8:10 a.m. near frame 41, while the ship lay moored at Battleship Row.
2. At 9:00 a.m. five 250kg bombs struck the ship almost simultaneously, causing fires and large holes in upper and main decks.
3. As a result of the fires, the boiler rooms were abandoned due to smoke.
4. Flooding continued progressively, with water eventually occupying the whole ship. Very few compartments below the water line were found dry.

Later that morning, the NEVADA was moved to Waipio Point with assistance of tugs, in order to prevent the ship from becoming a navigation hazard in the narrow channel near Hospital Point.

The Salvage and Repair Unit found on examination that the most serious obstacle to overcome was a hole created by the torpedo roughly 48 feet long by 25 feet deep. A large patterned form intended for the OKLAHOMA was diverted to the NEVADA. After dynamiting and dredging the bottom on which the ship rested, the patch was fitted to the vessel. To accomplish the task of repairing the NEVADA, over 400 dives were made by Navy and civilians (Pacific Bridge Company), totalling 1,500 diving hours.

Hazards were always present, and two fatalities occurred aboard the NEVADA from inhalation of hydrogen sulfide gas, which in high concentrations was undetectable and lethal. Later on, divers wore litmus paper on their suits to measure the gas.

On February 12, 1942, the NEVADA was refloated and sent to drydock No. 2. There the ship was repaired to be seaworthy for the voyage to Puget Sound Navy Yard, Washington. It arrived on May 1, 1942, and was reconditioned and modernized. In late December 1942 it rejoined the Pacific Fleet.

The USS CALIFORNIA (Battleship)

The CALIFORNIA was struck by two torpedoes and one bomb (250 kg) that resulted in a serious fire. The flooding of the vessel was slow but progressive. Two factors played in the loss of the CALIFORNIA: 1) Water and oil permeated the vessel due to open manholes, ventilation systems and ruptured pipelines. This caused the abandonment of fire rooms and engine rooms. 2) An oil fire from the ARIZONA drifted down and around the CALIFORNIA resulting in a temporary abandonment of the ship at the most critical moment in which the crew was attempting to keep the CALIFORNIA afloat.

Eventually, the crew returned and counterflooded to correct a list of 16 degrees. The vessel avoided turning turtle by this method and settled on the bottom.

A few days after the attack the ship was evaluated for salvage and repair. The immediate need was to lighten ship. All nonessential material, fuel, ammunition, machinery and main gun batteries were removed. Salvage workers placed cofferdams around the ships forecastle and quarterdeck. The water was then pumped out of the flooded spaces and the CALIFORNIA was refloated on March 24, 1942. One incident did mar the successful salvage of the CALIFORNIA. On April 5, 1942, prior to the ship going into drydock, a powerful explosion ripped the CALIFORNIA. It appears that gasoline vapor built up in a fuel storage compartment and was ignited by a naked light bulb or defective wiring. The result was the loss of a window frame patch. The setback was only temporary. The ship was placed in drydock No. 2 on April 9, 1942. During this time permanent repairs were made on the structural damage to the ship. In October of that year, it steamed back to the West Coast and underwent further repair work and modernization at Puget Sound Naval Yard. Less than a year later, the CALIFORNIA returned to the fleet.

The USS WEST VIRGINIA (Battleship)

During the attack, the WEST VIRGINIA was moored just forward of the ARIZONA. Berthed next to the WEST VIRGINIA was the TENNESSEE. Being the outboard ship, the WEST VIRGINIA received perhaps seven torpedo hits. The exact number may never be known because of the extensive damage done to the port side. At least three torpedoes smashed below the armor belt, and one or more struck the armor belt, displacing it. Possibly two torpedoes went through holes made by the first torpedo hits causing explosions within the armored second deck and wrecking the aft steering gear, resulting in the loss of the rudder. Fortunately, the two bombs that struck the WEST VIRGINIA were duds. One pierced gun turret No. 3 and the other passed through the foretop and landed on the second deck.

Damage to the ship's port side was extensive, and the hull damage was so serious that the vessel proved difficult to raise. The chief problem with salvaging the ship was sealing the hull. The use of special underwater concrete and huge patches measuring 13 feet by 50 feet enabled the WEST VIRGINIA to be raised. More than 800,000 gallons of fuel oil was pumped out of the vessel. More than 67 bodies were removed from the ship. Of particular note were three bodies found in a storeroom near the ship's fresh water pump. Empty cans and marks on a calendar gave evidence that they had survived until December 23, when the air gave out.

On May 17, 1942, the WEST VIRGINIA was refloated and entered drydock

No. 1 on June 9. Temporary repairs were made at this time to ready the vessel for its cruise to Puget Sound for permanent repairs and modernization. On July 4, 1944, the "Wee Vee" returned to the Pacific Fleet.

The USS OKLAHOMA (Battleship)

As the Japanese torpedo planes made their initial runs on Battleship Row, the OKLAHOMA received much of their attention. It is estimated that five to seven torpedoes struck the vessel during the first 15 minutes of the attack. Damage was so extensive that the OKLAHOMA capsized at its berth.

In a memorandum to the chief of naval operations from Rear Admiral William Furlong, commandant of Pearl Harbor's Navy Yard, dated October 17, 1942, the condition and salvage summary of the OKLAHOMA was outlined. Of particular note was the section on the ship's general condition.

> The vessel capsized in approximately 40 feet of water through an angle of 150 degrees to port (away from Ford Island) at Berth F-5, where the ship was moored outboard of the USS MARYLAND. At mean low water the center line at keel is about one foot above water at the after end of the skeg just forward of the rudder and about 2 1/2 feet below water at the bow. This center line is approximately 215 feet away from quay F5-S and 245 feet from F5-N, measured horizontally and normal to the line of the quays. Reports from survivors and examinations by divers both inside of the vessel by entering through the bottom of the ship to the underside of the second deck and outside the ship indicate that there is considerable damage along the port side due to torpedo hits and near misses by bombs. The exterior examination indicates five areas of damage above the mud line centered respectfully at frames 38, 43, 56, 80 and 97 and interior diving operations thus far completed have revealed structural damage on the port side of the third deck from frames 48 to 68 and from 90 to 95, and on the first platform from 48 to 68. There appears to be complete penetration into boiler room No. 2 (forward port side). Soundings indicate that the port side of the ship and the superstructure are buried in mud to maximum depth of 20 to 25 feet. The masts are bent or broken and lying approximately horizontal near the surface of the mud. Analysis of test borings show that from frame 54 aft, the ship is resting on comparatively solid material, whereas the forward end is essentially floating in soft mud. This soft material increases in depth toward and beyond the bow of the ship.

Captain Wallin voiced an opinion that the size of the OKLAHOMA and the ship's general condition made salvage questionable. It was also expressed, however, that it was important to rid the harbor of this derelict ship and make the berth at F-5 available for other ships. By May 1942, contractual agreements were made between the Navy and Pacific Bridge Company to complete that task. It has been said that the righting of the OKLAHOMA was the most technically difficult task faced by the salvage division at Pearl Harbor.

After much discussion and planning, the solution was found. Twenty-one electric winches fastened to the shoreline of Ford Island would pull the ship over by means of cables attached to 40 foot wooden and metal struts bolted or welded to the upturned hull of the ship. Before any of this could occur, 350,000 gallons of fuel oil were pumped out of the ship's tanks, and nearly 2,000 tons of coral soil were dumped onto the harbor floor to prevent the vessel from slipping along the bottom once the righting began.

The righting operation began on March 8, 1943, and was eventually completed by June 16 of that year. With the ship upright, patches were needed to repair the gaping holes along the port side of the ship. In all, seven were required to seal the port side. As in the case of the USS WEST VIRGINIA, underwater concrete called tremie sealed the sections that were patches. It was during this period that the grim task of removing 400 bodies was completed.

The ship was refloated on November 3, 1943, and taken into drydock No. 2 on December 28. There it was stripped of its equipment, auxiliary machinery, guns, stores and ammunition.

With new classes of battleships appearing in the fleet, it was felt that it was not worth the effort and expense to restore the badly damaged OKLAHOMA to service. The ship was decommissioned on September 1, 1944. During the years up to 1947, the ship was moored at Middle Loch, Pearl Harbor. In 1947, it was sold for scrap for $146,000 to the Moore Drydock Company on the West Coast. On May 10, 1947, the OKLAHOMA left Pearl Harbor for the last time. While under tow by two tugs, it was lost 540 miles northeast of Pearl Harbor on May 17.

The USS OGLALA (Minelayer)

On the morning of the attack, the OGLALA was moored outboard of the cruiser HELENA at 1010 dock. A torpedo passed underneath the OGLALA and struck the cruiser on the starboard side. The concussion of the explosion ruptured the lower port shell (hull) plating, causing extensive flooding and eventual sinking. It was realized early on that the vessel was going to be lost so the tug HOGA was brought along side to move the ship to the stern of the HELENA at dockside. It was there it rolled over on its starboard side.

Because the ship was so old, there was no great priority to press it back into service. However, the clearing of 1010 dock was of vital importance to the naval facility. Several solutions were drawn up to deal with the OGLALA. The most radical was to dynamite the ship and remove the broken sections for scrap. This idea was set aside when it was realized how much explosives would be needed to complete the work.

The solution that did prevail was the use of salvage pontoons. The process was rather simple in application. The pontoons would be sunk alongside of the vessel and the ship pumped dry. With the ship sealed, the pontoons attached by cable, were inflated, thus lifting the ship.

As simple as the process sounded, the raising of the OGLALA was not a simple task. The first attempt on April 11, 1942, failed when the pontoons broke lose. The second attempt on April 23 was successful in raising the vessel but failed when an underwater pump stopped working. The third attempt almost caused the ship to sink once again, when a fire broke out aboard ship on July 2, 1942.

Finally, a day later it entered drydock No. 2 for temporary repairs so that it would be seaworthy for its trip to the Navy Yard at Mare Island in California. By February 1944, it was reconditioned and placed back into service.

Conclusion

By late 1944, Captain Wallin and his salvage teams had completed their task. The greatest maritime salvage operation the world had ever witnessed was history. Eighteen of 21 vessels had been returned to service. Supposedly insurmountable obstacles had been overcome by courage and skillful engineering. Lack of materials, fire and gas hazards, removal of explosives, extensive diving in hazardous waters and the removal of bodies were but a few of the major problems facing the salvage workers.

In a cooperative effort, the civilian companies and the military authorities had achieved what others had deemed impossible. Overshadowed often by the disastrous day of infamy, it is a small footnote of history yet to be fully explored.

Japanese Naval Aircraft at Pearl Harbor

At 6:05 a.m. the six aircraft carriers of the Japanese strike force swung eastward into the wind and increased speed. Packed on their decks were the finest carrier aircraft in the world in 1941, the famed Zero (fighter), the Kate (torpedo/horizontal bomber) and the Val (dive bomber).

A majority of the pilots were combat veterans from missions flown in China. Japan offered its best ships, planes and pilots to guarantee a successful attack on the United States at Pearl Harbor. The world that day would witness a new type of weapon that would change history. It was the dawn of large-scale carrier warfare.

Three hundred and fifty aircraft had roared off the decks of their pitching carriers toward Hawaii. Two separate waves of aircraft would make up the strike force launched at two intervals. By noon 321 had returned, 29 planes and 55 airmen having been lost.

The amazing military achievement was not a random piece of luck. Many years of research and development of the planes were paid off in Japan's success at Pearl Harbor. On that day, the Japanese utilized the most modern types of carrier aircraft. Five plane types were used in the "Hawaii Operation": The float plane (scouting), fighter, dive bomber, torpedo plane, and the horizontal bomber.

AICHI E13A1 Float Plane

The first to be launched that day was an Aichi E13A1 (Jake) float plane, designed in 1938 to replace the aging Type 94-95 reconnaissance float planes built by Nakajima in 1933. The new float plane was intended to operate from cruisers and seaplane tenders. Its primary mission was reconnaissance but on occasion the aircraft was used for bombing missions, air-sea rescue, staff transport and, as the war became more desperate, kamikaze attack.

The major defects of the aircraft were lack of fuel capacity, armor protection of the crew, and limited defensive armament. On the positive side it was a reliable machine able to stay aloft for 15 hours.

At 5:30 a.m. on December 7, 1941, the cruisers CHIKUMA and TONE each catapulted into the darkness a AICHI E31A1 to scout the anchorages at Pearl Harbor and Lahaina Roads, Maui. The planes, on reaching their destination, would scout for about 15 minutes to insure that their reports would be accurate. Their message back to the fleet would break the spell of radio silence that had been in effect since the fleet had sortied in late November 1941. Two hours later the CHIKUMA's float plane signaled "Enemy fleet in port."

TECHNICAL DATA

Description: Single-engine twin-float reconnaissance seaplane. All metal construction with fabric-covered control surfaces.

Accommodation: Crew of three in tandem, enclosed cockpits.

Powerplant: One Mitsubishi Kinsei 43 14-cylinder air-cooled radial, rated at 1,060 hp for takeoff and 1,080 hp at 2,000m (6,560 ft). driving a three-blade metal propeller.

Armament: One flexible rear-firing 7.7mm Type 92 machine-gun and One flexible downward-firing 20mm Type 99 Model 1 cannon (field modification on late production aircraft).

External load: one 250kg (551-lb.) bomb. or four 60kg (132-lb.) bombs or depth charges.

Dimensions: (E13Ala) Span 14.5m (47 ft. 6 7/8 in.): length 11.3m (37 ft. 0 7/8 in.); height 7.4m (24 ft. 3 11/32 in.); wing area 36 sq m (387.499 sq ft.).

Weights: (E13Ala) Empty 2.642kg (5,825 lb.); loaded 3,640kg (8,025 lb); maximum 4,000kg (12,192-lb.): wing-loading 101.1kg/sq m (20.7 lb./sq ft.); power-loading 3.4kg/hp (7-6 lb/hp).

Performance: (E13Ala) Maximum speed 203 knots at 2,180 m (234 mph at 7,155 ft); cruising speed 120 knots); range 1,128 nautical miles (1,298 st miles).

Production: A total of 181 E13Als were built between 1938-1942.

Aichi Tokei Denki K.K., Funakata: 133 aircraft (1938-42)

Dai-Juichi Kaigun Kokusho, Hiro: 48 aircraft (1940-42)

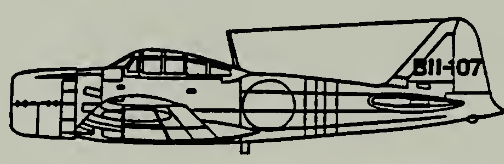
Mitsubishi A6M2 Type 21 Reisen Zero Fighter

The Mitsubishi Reisen Zero fighter was considered by many aviation experts to be the finest aircraft of its type in 1941. It was this model that had such an impact in the attack on Pearl Harbor.

The chief designer of the aircraft was Jiro Horikoshi. He and his design team developed a model of an all-metal monoplane, with a low-wing configuration and powered by 780 HP Mitsubishi engine. The first flight test occurred in April 1939. The initial interest and authorization came from the Imperial Navy, which sought a fighter aircraft that could carry two 60kg (132 lb) bombs, and that could fly at 311 mph, climb quickly, cruise in the air for 6-9 hours, be armed with two 20mm cannon and two 7.7mm machine guns, take off in less than 230 feet, and outmaneuver anything that Japan had flown before. After flight testing and modifications, the Model A6M2 wheeled out of the production plant in December 1939. The aircraft surpassed its navy's expectations.

As the Pacific War approached, several alterations were introduced to the Zero. The most important change was installation of folding wing tips, an alteration that allowed the aircraft to use existing deck elevators on the carriers. This Model A6M2, Navy Type 0 Model 21 was the aircraft that flew over the Island of Oahu.

It is estimated that the Japanese navy had 521 fighter planes -- 328 of them A6M2s -- at the time of the attack on Pearl Harbor. A force of 79 Zeros was sent against Pearl Harbor, and nine were lost in action. This force effectively neutralized American air power on Oahu in less than two hours.



Mitsubishi A6M (Zeke)

The Zero's success lasted until 1943, when the Allies began producing superior aircraft that rendered it obsolete. Still, despite the loss of superiority, the Zero continued to be produced and flown in combat until war's end.

TECHNICAL DATA

Description: Single-seat carrier-borne fighter, all-metal construction with fabric-covered control surfaces.

Accommodation: Pilot in enclosed cockpit.

Powerplant: One Nakajima NK1C Sakae 12 14-cylinder air-cooled radial, rated at 940 hp for takeoff and 950 hp at 4,200 m (13,780 ft), driving a three-blade metal propeller (A6M2).

Armament: Two 7.7mm Type 97 machine-guns in the upper fuselage decking and two wing-mounted 20mm Type 99 cannon. (A6M1, A6M2, A6M3, A6M5 and A6M5a).

Performance:
Maximum speed: 288 knot at 4.550m (331.5 mph at 14,930 ft)
Cruising speed: 180 knot (207 mph)

Climb to: 6,000m (19,685 ft) in 7 min 27 sec.

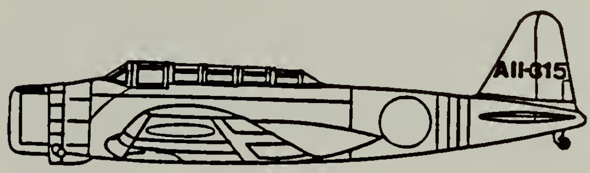
Service ceiling: 10,000m (32,810 ft)

Normal range: 1,010 nautical miles (1,160 st miles)

Maximum range: 1.675 nautical miles (1.930 st miles)

Nakajima B5N2 "Kate" Torpedo/Horizontal Bomber

In 1932 the Japanese began to develop a new series of carrier attack bombers capable of delivering torpedoes as well as bombs. Over a period of one year, the Japanese navy issued specifications needed to fulfill the needs of carrier warfare. Three companies in particular -- Aichi,



Nakajima B5N (Kate)

Mitsubishi and Nakajima -- offered prototypes to meet the specifications. After careful evaluations were made, the navy again reissued the specifications in the hopes that it would be able to replace the B4Y1 Type 96 carrier attack bombers that had been accepted as a stopgap measure until suitable aircraft could be developed.

The new specifications called for a wingspan less than 52 feet 5 inches that could fold down even further and reduce the wingspan to 24 feet 7 inches. The airspeed must be in the area of 207 mph at 6,560 feet. For endurance it must be able to fly four hours at normal cruising and seven hours maximum. The crew must consist of three airmen. As for armament, it had to be able to carry a bomb load of 1,764 pounds, either torpedo or equivalent bombs. To defend itself from aerial attack, a 7.7mm machine gun was to be mounted in the rear cockpit for crew operation. The general design was specific, as it called for a single engine monoplane.

In the competitive trials for a suitable design, the Nakajima team led by Katsuji Nakamura presented the Japanese navy with a configuration that went beyond expectations. The new aircraft, known as a Type K, was a sleek low-wing design with several options that made the craft ideal for future carrier operations. Among these innovations were: hydraulically operated undercarriage, folding wings, shortened fuselage (33 feet 9 inches) so that it could be used on existing carrier elevators in the fleet, and an airspeed of 230 miles per hour.

After months of flight testing, the aircraft (Type K) was redesignated (B5N1) Navy Type 97 carrier attack bomber model II. This aircraft flew from 1937 to 1939 where it saw limited action in the war with China. Because of the increased use of modern fighter aircraft being used by the Chinese, the Japanese saw a need to improve the aircraft to insure its survivability in combat. This led to the Navy Type 97 carrier attack bomber model 12 or B5N2. This aircraft had no external changes and was almost identical to the earlier B5N1. A dramatic change took place, however, internally. The main power plant had been the 9-cylinder Hikari 3 engine. In an effort to increase reliability, cowling-size reduction (increased visibility for pilot) and a small propeller spinner (reducing drag, that is, a cooler engine), the 14-cylinder double row Sakae II was adopted.

As the Japanese fleet trained in 1941, the B5N2 played a critical role in preparation for the Hawaii Operation. This aircraft had replaced all B5N1s and B4Y1s as the first line plane. At this point in history, Japan possessed the finest horizontal/torpedo bomber in the world.

Critical to the attack on Pearl Harbor was the successful execution of a torpedo attack on an anchored vessel. A great deal of training and technical engineering concerns had to be solved prior to the assault on Pearl Harbor. Fortunately for the Japanese, the training had gone well and the technical problems associated with shallow water torpedo attack were solved. However, one pilot, Lt. Jinichi Goto recalled:

> We were told after reviewing what we have trained, we will start practicing against ships at anchor. They were anchored 500 meters from shore and we were supposed to attack from land. The depth of water was 12 meters. We were shocked to hear about it. To us it sounded senseless and we did not think we could do it . . . In the beginning I was very nervous. I had stiff shoulders and my hands were shaking, but after a while I got used to it.

The fleet sailed for Hawaii in late November. Almost half of the attacking force was made up of B5N2s. A total of 143 planes, 40 torpedo bombers and 103 horizontal bombers were used that day. It was a spectacular success for the pilots and planes against the Pacific Fleet. For Lt. Goto, the attack on the battleship USS OKLAHOMA had left a lasting impression.

> I was shocked to see the row of battleships in front of my eyes . . . I flew diagonally not knowing which was the bow and which was the stern. All I saw was the mast, the bridge and smokestack . . . three things were the key elements to the attack. Speed must be 160 knots per hour, the nose angle zero (meaning horizontal to the sea), an altitude 20 meters. We were told if one of these were off, it would change the angle and the torpedo would go deep under the water and miss the target . . . I didn't have time to say ready, so I just said fire. The scout man on the back pulled the release lever. The plane lightened, with sound of the torpedo being released. I kept on flying low and flew right through, just above the ship . . . I asked my observer "Is the torpedo going all right? . . . Soon he said "It hit it" . . . Eventually, Murata's and my torpedo hit the mark. I saw two water columns go up and smoothly go down . . . But then I realized we're being attacked from behind . . . I was avoiding bullets by swinging my plane from right to left. I felt frightened for the time and thought my duty was finished. I headed back to the meeting place.

In just 15 minutes, the main battle line of the Pacific Fleet had been smashed. Large-scale operations of carrier warfare had come of age, and the old notion of battleship dominance slipped beneath the waters of Pearl Harbor.

As the war progressed, the decline of the B5N2 as a viable front-line weapon was evident. By 1944, staggering losses and insufficient performance regulated the aircraft to second-line units. However, the Kate found a new avenue of effectiveness as a reconnaissance and antisubmarine aircraft. Because of its long flight time, the Kate was able to escort convoys and protect them from submarine attack. Radar and more sophisticated electronic gear were fitted to the plane to enhance the aircraft's effectiveness.

TECHNICAL DATA

Description: Single-engine three-seat carrier-borne torpedo bomber, all-metal construction with fabric-covered control surface.

Accommodation: Crew of three: pilot, observer/navigator/bomber-armer and radio-operator/gunner. Cockpit enclosed.

Powerplant: One Nakajima NK1B Sakae ii 14-cylinder air-cooler radial rated at 1,000 hp for takeoff, and 970 hp at 3,000m (9,845 ft.), driving a three-blade constant-speed metal propeller.

Armament: One flexible rear-firing 7.7mm Type 92 machine gun. Bomb-load: 800kg of bombs, or one 800kg (1,764 lb) torpedo.

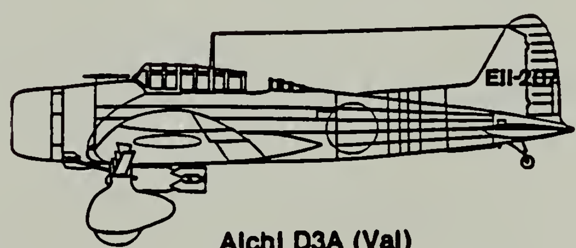
AICHI D3A1 Type 99 Carrier Dive Bomber

The Japanese navy, in the summer of 1936, issued a specification call (II-Shi) for a carrier-based airplane with dive-bombing capabilities. The specifications called for a monoplane design. As usual, the leading manufacturers submitted designs. Mitsubishi, Nakajima, and Aichi received contracts to build prototypes.

After tests were completed, the Aichi company was ready to compete for the contract. One unusual characteristic of the Val was its fixed and spatted undercarriage -- the fixed landing gear added weight and decreased performance, but actually added stability to this particular design.

A second prototype was constructed with the enlargement of the wings, tail and stabilizers. An increased powerplant capacity was fulfilled by the addition of a Mitsubishi Kinsei No. 3, a 14-cylinder air-cooled radial engine. As with the first prototype, the aircraft carried two seats, one for the pilot and one for the rear gunner/radio operator.

It was later found that, because the aircraft was so maneuverable, the Val could be used as a fighter plane despite the light armament of two 7.7mm Type 97 machine guns (mounted on the engine cowling) and one flexible 7.7mm Type 92 rear-mounted machine gun.


Aichi D3A (Val)

The Val carried a 250kg (551-pound) bomb under the fuselage that was released via a swing arm. In addition, two 60kg (132-pound) bombs could be carried on racks under each wing.

Carrier qualification trials were held aboard the AKAGI and KAGA in 1940 with satisfactory results. Vals saw limited action in China in the year preceding the attack on Pearl Harbor.

Historians for the most part agree that the first bombs to fall at Pearl Harbor came from Lt. Commander Kakiuchi Takahashi's attack group of dive bombers that struck the PBY ramp at Ford Island. For the AICHI Vals, the day proved successful but costly -- a majority of the 29 aircraft lost were Vals.

Like the NAKAJIMA Kate, the Val enjoyed early success in the war but by 1944 it was suffering heavy losses and was outperformed by allied aircraft. As the war drew to a close, the AICHI D3A1 Val was pressed into Kamikaze units.

UNITS ALLOCATED

Carriers: KAGA, SORYU, HIRYU, *AKAGI, ZUIKAKU, SHOKAKU
*Division flagship

TECHNICAL DATA

Description: Single-engine carrier-borne and land-based bomber. All-metal construction with fabric-covered control surfaces.

Accommodation: Crew of two: pilot and radio/rear gunner in tandem in enclosed cockpit.

Powerplant: One Mitsubishi Kinsei 3 radial engine, rated 840hp for takeoff, and 730hp at 5,250 ft. driving a three-blade metal propeller.

Japanese Naval Crash Site Report 1986

Introduction

A summary report was assembled on possible crash sites of Japanese naval planes lost over Pearl Harbor. Evaluations were made based on ships' charts and testimonies of eyewitnesses.

The report was completed on June 25, 1986 (Martinez 1986). Based on its findings, the Submerged Cultural Resources Unit developed an archeological plan to investigate crash sites located in the waters of Pearl Harbor.

In compiling these data concerning crash site areas, the main evidence used are charts filled in by individual ships that witnessed the attack.

On December 21, 1941, Commander in Chief Vice Admiral William Pye directed by memo that all ships present were to fill out three track charts of Pearl Harbor (U. S. Navy 1941) . The information required was:

Chart I - Gunfire chart (rounds expended)

Chart II

A) Ships track on sortie

B) Track on sortie and continuation of Chart I

C) Continuation Chart I

Chart III - Enemy Planes Seen, Shot down

Of special note were the directions given to aid the plotters:

> On this chart, use the same symbols as on chart I, (T) - Torpedo plane, (H) - Horizontal bomber, (D) - Dive bomber, (F) - Fighter or Pursuit, indicating approximate location by (+) and the symbol of the type in red pencil. If a plane was actually seen in flames, mark the spot where last seen by the symbol of the type and write "flames."

One hundred ship charts were used to compile this report. Each report was tallied and sources evaluated to determine a probable crash site. The more ships that point to one particular spot obviously increase the possibility of a downed aircraft.

The parameters of this report are specific and only concerned with aircraft lost by the Japanese on December 7, 1941, at Pearl Harbor.

Methodology

Based on the reports of 100 vessels present during the Pearl Harbor attack, it is possible to make some observations as to the possible sites of downed Japanese naval aircraft.

The basis for these inferences was the weight of historical evidence. A total of 35 crash sites were charted (U.S. Navy 1942). Obviously some were erroneous, because only 29 aircraft were lost in the attack and not all were downed in the vicinity of Pearl Harbor.

Three sources were used in evaluation of the ship charts:

A) Reports of 100 ships present during attack responding to Pye's memo (U.S. Navy 1941).

B) Master Map assigning a number to each crash site (U.S. Navy 1942).

C) Oral Testimony concerning crash sites.

It was possible to determine which sites held the greatest chance for discovery of Japanese naval aircraft remains.

The Evidence

A total of 35 sites were indicated on the 1942 ship charts. Evaluation of the evidence shows that 14 were located on land and 20 on water. The thrust of this investigation was to find which water crash sites held the most promise. Based on that criteria, 13 sites should be examined. They are as follows (see Figure 3.36):

The Crash Sites

1) Site No. 2

Location - in East Loch near the stern of the USS DOBBIN.

Evidence - 8 reports

Conclusion - Aichi D3Al Val Dive Bomber.

2) Site No. 5

Location - near the mouth of Middle Loch, in or near channel. Around Ford Island, on starboard side of the USS CURTISS.

Evidence - 12 reports

Conclusion - Aichi D3Al "Val" Type 99, Dive Bomber.

3) Site No. 7

Location - in the Southeast Loch near Kaahua Point.

Evidence - 21 reports

Conclusion - Nakajima B5N2 "Kate" Torpedo Bomber

4) Site No. 8

Location - on the channel northeast of Battleship Row, just off the port stern of the USS NEVADA.

Evidence - 11 reports

Conclusion - Nakajima B5N2 "Kate" Torpedo Bomber

5) Site No. 12

Location - in East Loch, just off the bow of the USS SOLACE.

Evidence - 4 reports

Conclusion - Aichi D3A1 "Val" Type 99, Dive Bomber

6) Site No. 18

Location - in Middle Loch near the Pan Am Clipper landing, just east of Pearl City.

Evidence - 4 reports

Conclusion - Aichi D3A1 "Val" Type 99, Dive Bomber

7) Site No. 19

Location - crash occurred on seaplane tender USS CURTISS. Some wreckage could be found in the vicinity of the mouth

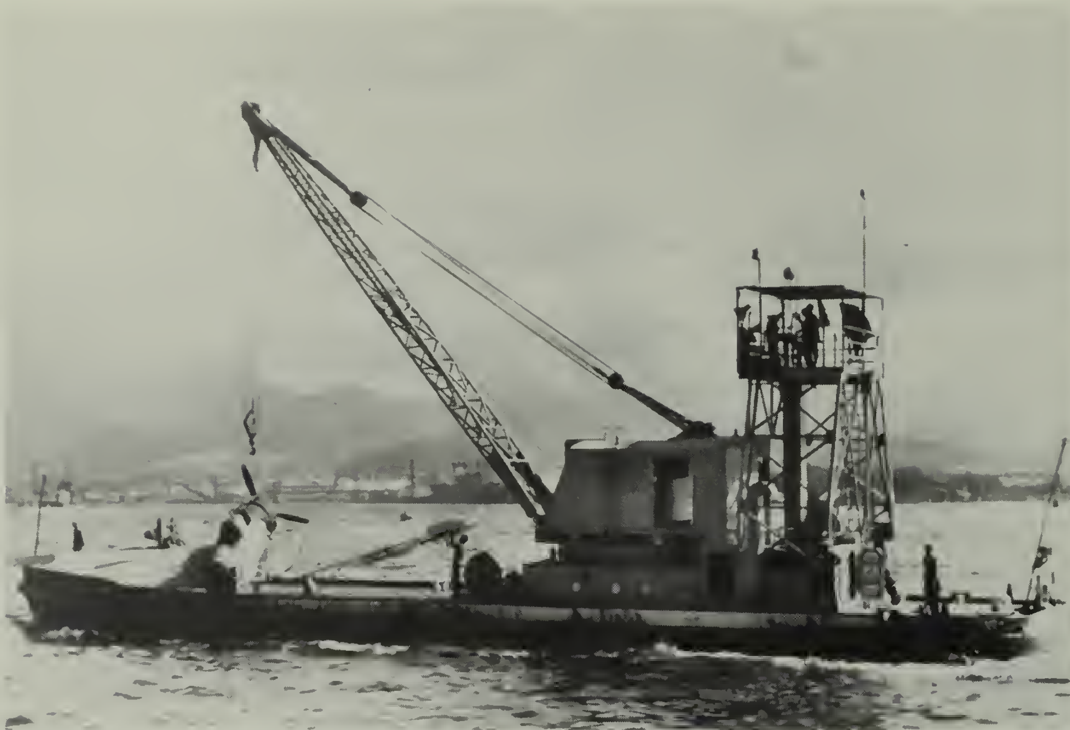


Figure 2.41. "Val" dive bomber being removed from Pearl Harbor after the attack. (NPS: USAR Collection)

Figure 2.42. Close up of "Val" that crashed during the attack. (NPS: USAR collection)

of Middle Loch on the north side, near Pearl City.

Evidence - 11 reports

Conclusion - Aichi D3A1 "Val" Type 99, Dive Bomber

8) Site No. 20

Location - near Merry Point Landing in the Southeast Loch.

Evidence - 8 reports

Conclusion - Nakajima BN52 "Kate" Torpedo Bomber

9) Site No. 26

Location - in the channel east of Ford Island, approximately 1,000 yards from the USS ARIZONA

Evidence - 7 reports

Conclusion - Nakajima BN52 "Kate" Torpedo Bomber

10) Site No. 4

Location near the shoreline of Beckoning Point

Evidence - 14 reports

Conclusion - Aichi D3A1"Val" Type 99, Dive Bomber

The sites below are less well-documented than the others, but appear to be worthy of investigation.

11) Site No. 23

Location near the 1010 dock in area of mooring of the OGLALA and HELENA.

Evidence - 3 reports

Nakajima BN52 "Kate" Torpedo Plane

12) Site No. 22

Location - near the starboard stern of the USS SOLACE.

Evidence - 3 reports

Probable Type: Cannot determine, could be either Val or Kate.

13) Site No. 31

Location - in Middle Loch between the bow of the CURTISS and the MEDUSA.

Evidence - 69D, 70D, 100T

Aichi D3A1 "Val" Type 99, Dive Bomber.

The following is a prioritized list of 13 crash sites that were selected for investigation, based on the number of citations from ship reports regarding a particular crash site (see Figure 3.36).

Site No. 7
Site No. 4
Site No. 5
Site No. 19
Site No. 8
Site No. 20
Site No. 2
Site No. 26
Site No. 18
Site No. 12
Site No. 23
Site No. 22
Site No. 31

These were selected for side-scan survey and review. Charts of ongoing and previous dredging of Pearl Harbor pointed to massive alteration of the harbor bottom by dredging, which may have eradicated many of the crash sites.

The Japanese Midget Submarines at Pearl Harbor

The Mission

As plans and preparations were being made in 1941 for Japan's Hawaii Operation, Admiral Isoroku Yamamoto decided that a special submarine force would attack in concert with carrier-borne aircraft at Pearl Harbor.

The development of submersible craft as weapons for naval warfare began with the construction of small vessels. From Bushnell's "Turtle" and Capt. Horace Lawson Hunley's Confederate DAVID, through John Holland's FENIAN RAM and HOLLAND I, submersibles grew larger, achieving greater size and effective use by the time of the First World War. The success of the "submarine" during the war led to increased programs of development and construction by various nations. In Japan, submarine development included "midget" submarines, and "while some scoffed at the potential of small undersea craft, others were deadly serious in a belief in their capability of dealing destructive blows to the enemy." (Stewart 1974:55). In 1933 Capt. Kishimoto Kaneji, I.J.N., designed two torpedo-shaped midgets as auxiliary weapons to be carried by fast surface vessels. Built in 1934 at Kure Navy Yard and known as "A-Hyoteki" or "A-Target," these vessels, with conning towers fitted as a result of experimentation, led to a later version, "A-Hyotelei," wherein two submarines, HA. 1 and HA. 2, were built in 1936. The midget program, operating under stringent security, commenced in earnest in 1938 as Ourazaki and Kure DY began the construction of 49 Type A vessels, HA. 3 through HA. 52. Among the vessels built during this initial burst of construction was HA. 19, which would later participate in the attack on Pearl Harbor. The beginning of the Second World War led to increased midget construction, including Type-A, Type-B, Type-C and Type-D boats, several experimental prototypes, and KAITEN-type manned torpedoes (Stewart 1974:55; Jentschura, Jung and Mickel 1986:183-184).

Following Admiral Isoruko Yamamoto's determination to attack the United States Pacific Fleet at Pearl Harbor as the opening blow of a war with the United States, military and naval planners began assembling the plan for the attack, which was designated "Operation Hawaii." Initially conceived as an air strike, the plan was modified to combat test the hitherto untested Type A midget submarines. The crews of the midgets, readying for war but not yet knowing their target, were notified in mid-October 1941 to concentrate their training on Pearl Harbor and Singapore, while the Sixth Submarine Fleet's large submarines were modified to carry the midgets piggy-back across the Pacific. Doubts about using the midget submarines plagued the Japanese planners, and as late as November 14, the final decision to employ them had not been made. On November 18, 1941, the mother submarines, each with a midget directly aft of the conning towers and attached to the deck by steel belts, departed Kure Navy Base for Pearl Harbor (Prange, Goldstein and Dillon 1981). Each midget carried two crewmen and two torpedoes. Each was 81 feet long, 6 feet in diameter, and powered by a 600-horsepower electric motor. The motor was generated by 224 short-lived Type D batteries, but the batteries could not be self-recharged: Thus the cruising range was limited to less than 100 miles.

Five I-class fleet submarines, I-16, I-18, I-20, I-22 and I-24 of the First Submarine Squadron, Sixth Submarine Fleet, each carrying a Type A midget, were designated as the "Special Attack Force." The midget submarines' mission was to covertly slip into Pearl Harbor, wait until the attack, and then each launch their two torpedoes. They would then navigate submerged, counterclockwise around Ford Island, escape and meet up with their mother subs 7 miles west of Lanai Island. Reaching their destination on December 5, 1941, the five submarines fanned out in their deployment pattern off Pearl Harbor, closing to within 10 miles of the harbor entrance (Stewart 1974:57; Prange, Goldstein and Dillon 1988:49).

The first midget submarine launched was from I-16. Manned by Ensign Masaharu Yokoyama and Petty Officer 2nd Class Tei Uyeda, the midget left at midnight. At 1:16, I-22 released the midget commanded by Lt. Naoji Iwasa, leader of the midget submarines. At 2:15, I-18 launched the third midget, that of Ensign Shigemi Furuno and Petty Officer 1st Class Shigenori Yokoyama. At 2:57, the fourth midget submarine was launched from I-20. This midget was commanded by Ensign Akira Hiroo accompanied by Petty Officer 2nd Class Yoshio Katayama. Last to launch was HA. 19 from I-24 at 3:33. Commanded by Ensign Kazuo Sakamaki and Chief Warrant Officer Kiyoshi Inagaki, HA 19 slipped off the deck of I-24 about 10 1/2 miles off Pearl Harbor and headed for the lights of Honolulu (Prange, Goldstein and Dillon 1981).

One of the fears of the attack planners was that the presence of the submarines would give away the Japanese intent. The fear was justified; however, U.S. forces did not understand the significance of sighting a submarine within the Pearl Harbor defensive zone until too late. The first midget submarine sighting was by the minesweeper USS CONDOR. At 3:42, 1 3/4 miles south of the Pearl Harbor entrance buoys, CONDOR spotted a periscope. The minesweeper notified the destroyer USS WARD, whose commander, Capt. William Outerbridge, searched without success until 4:45. The next sighting came an hour later. At 5:45, the USS ANTARES' crew, towing a target into the harbor, spotted a submarine following them in. The submarine's conning tower was exposed. A seaplane spotter dropped smoke pots off the submarine at 6:33, giving the WARD a fix. At 6:37 the WARD spotted the midget behind the ANTARES at 12 knots, obviously making a run for the harbor. Captain Outerbridge made a decision in just three minutes to attack. Sounding general quarters at 6:40, the WARD's engines surged full ahead as the gun crews loaded the deck guns. No. 1 gun opened fire at 6:45 and missed; immediately No. 3 gun fired, hitting the submarine at the conning tower's junction with the hull. The submarine heeled to starboard, slowed and sank. The WARD depth-charged the sinking vessel as it plunged 1200 feet down, and at 6:46 ceased fire. The United States Navy, which had traded shots with German U-Boats in the Atlantic and probably had sunk one, had just made its first confirmed kill in World War II, and the opening shots of the war preceded the air attack at Pearl Harbor by an hour. Outerbridge sent a message to CINCPAC at 6:51; "We have dropped depth charges upon sub operating in defensive sea area." An amended message was sent at 6:53: "We have attacked, fired upon, and dropped depth charges upon submarine operating in defensive sea area." Advance warning of an attack was not heeded, and at 7:50 the first wave of Japanese planes hit Pearl Harbor and other military bases on the island of Oahu (Prange, Goldstein and Dillon 1981).

At 8:17 the destroyer USS HELM's crew spotted a midget submarine hung up on the starboard side of the channel entrance. The submarine submerged but immediately popped up again at 8:18. The HELM fired upon the submarine, but it submerged again and slipped away. Meanwhile, inside the harbor, the USS ZANE, a minesweeper, spotted another midget submarine 200 yards aft of the MEDUSA at Berth K-23 at 8:30. The ZANE's report was noted, and at 8:32, CINCPAC sent out the alert "Japanese submarine in harbor." The seaplane tender CURTISS opened fire at a midget submarine inside the harbor at 8:36; the submarine fired a torpedo at the tender that missed. As the CURTISS brought additional guns to bear, the destroyer USS MONAGHAN spotted the submarine and ran full speed toward it in an attempt to ram. Just as the submarine surfaced, damaged by the CURTISS's shot to the conning tower, the MONAGHAN struck it a glancing blow as a second torpedo passed

Figure 2.43. "The Nine Young Gods." Nine of the 10 midget-sub crewmen that took part in the Pearl Harbor attack. Conspicuous in his absence is the one survivor who was captured. (NPS: USAR collection)

Figure 2.44. One of the midget subs being removed from the bottom in 1960. Note torpedoes still in tubes. (NPS: USAR collection)

Figure 2.45. Japanese midget submarine HA. 19 beached at Bellows on the northern or windward side of Oahu. Photo by Signal Corps (NPS: USAR collection)

Figure 2.46. Conning tower of Japanese midget submarine HA. 19. (NPS: USAR collection)

harmlessly beneath the destroyer and exploded on the bank. Dropping two depth charges, the MONAGHAN finished off the midget submarine (Prange, Goldstein and Dillon 1988:234-236).

Outside the harbor, other Navy vessels were depth-charging numerous submarine "contacts." At 10:04 the cruiser USS ST. LOUIS was missed by two torpedoes. Spotting a midget submarine, the crew fired upon and apparently sank it. The WARD, whose crew claimed first blood at Pearl Harbor, depth charged four separate "contacts" between 10:20 and 11:50. At 17:15, the USS CASE depth charged another target. Meanwhile, aboard the mother submarines, the Special Attack Force awaited news from its comrades. At 22:41, I-16 received a radio message from the midget submarine commanded by Ensign Yokoyama, "successful surprise attack." (Prange, Goldstein and Dillon 1988:311-313). According to historian Gordon W. Prange:

> On this slender evidence the Japanese Navy concluded that at least three midget submarines had penetrated Pearl Harbor and, after the air raid, had inflicted severe damage, including the destruction of a capital ship. Quickly the word spread that the minisubs had sunk the ARIZONA. During the spring of 1942, the Japanese Navy released this to the press, and the midget submariners were venerated as veritable gods, to the resentment of the fliers, who knew exactly when and under what circumstances the ARIZONA had exploded (Prange, Goldstein and Dillon 1988:361).

While the submariners were venerated as the "heroes of Pearl Harbor" by Japanese and German propagandists, the actual record was dismal; the midget submarines did not achieve any success at Pearl Harbor. On the evening of December 7 and 8, the mother I-submarines met at the Lanai Island rendezvous, but the midgets did not return. The last contact was by radio at 1:11 on December 8 when I-16 heard from Ensign Yokoyama once again. By that time, Yokoyama and his crewman, and Ensign Kazuo Sakamaki and Chief Warrant Officer Inagaki in HA. 19 were probably the last midget submariners alive.

Designated "Midgets A through E" by the United States Navy (for the order in which the U.S. encountered them), the midget submarines have been gradually accounted for. "Midget A," sunk by the USS WARD, has possibly been located in 850 feet of water by a joint U.S. Navy/National Park Service submerged cultural resources survey of Pearl Harbor in the Summer of 1988. Immediately after the attack, "Midget B," rammed and sunk by the MONAGHAN, was raised and buried in landfill at the Submarine Base in 1942. Subsequently disinterred and then reburied again, the midget still lies in coral and sand fill as a permanent part of the base it attacked. "Midget C," HA. 19, washed ashore on December 8 and was captured. "Midget D" was located by Navy divers on a training exercise in 1960. Raised, it was returned to Japan and is now a memorial at the Submarine School at Eta Jima. Only "Midget E"'s location is unknown; if Ensign Yokoyama slipped out to sea in a failed attempt to rendezvous with the mother subs, "E" might hold his remains (Stewart 1988).

West Loch Disaster

Pearl Harbor is divided into a series of lochs that fan out from Ford Island that sits in the center of harbor. West Loch was the staging area for the invasion fleets of the Pacific. In particular, vessels called LSTs or LCTs that had the capability to land on the shore, open their bows and deposit troops, stores and vehicles on the beach.

Figure 2.47. LST exploding during West Loch disaster in May 1944. (NPS: USAR collection)

Figure 2.48. Fighting fires at West Loch. Signal Corps photo. (NPS: USAR collection)

Figure 2.49. Burning LSTs at West Loch. (NPS: USAR collection)

Figure 2.50. Aftermath of West Loch explosions (NPS: USAR collection)

On Sunday morning, May 21, 1944, 29 LSTs readied for the invasion of Saipan, were nestled together at six berths. An LST carried a crew of 119 men and 200 marines, trucks, jeeps, and weapon carriers were carried on the main decks, all of which were loaded with ammunition and gas. Each vessel carried 80 to 100 drums of high-octane fuel on forecastle. Six thousand cubic feet of cargo ammunition was stowed on the deck with field guns and amphibious craft known as DUKWs. Besides the stores carried on by the troops and their vehicles, the ship had its own magazine and fuel capacity of 200,000 gallons. Drums of lubricating oil, fog oil smoke pots and floats were carried on the fantail -- an accident waiting to happen.

On May 21, 1944, at 3:08 p.m., an explosion blossomed out of LST-353. Apparently the blast originated near the bow of LST-963, where Army troops had been unloading mortar ammunition. Red hot fragments showered the clustered LSTs, igniting gasoline drums lined up on the exposed forecastles. In minutes, the explosions began to rip the invasion fleet apart. Fires began to blaze from stem to stern.

The explosions continued, damaging more than 20 buildings shoreside at the West Loch facility. For 24 hours fires raged aboard the stricken ships.

In all six LSTs were sunk and several severely damaged. Dead were 163 men and 396 were wounded.

Several investigations sought to find the reason for such a disaster, but no conclusive evidence as how it occurred was decided upon. Two major reasons have emerged as to the possible cause: The initial explosion was caused by gasoline vapor, or that one or more mortar shells exploded while being handled.

It was recommended that LSTs no longer be nested, so that disaster like that at West Loch could be avoided. Fleet Admiral Chester Nimitz disagreed. He felt that facilities were too limited at Pearl and that the nesting was necessary. "It is a calculated risk that must be accepted."

During the explosions and fires, firefighters had prevented further loss of ships that would have delayed the invasion of Saipan. As it was, only a day was lost in the departure of the invasion fleet.

Today, only a few reminders of the West Loch disaster remain. For years, both during the war and after, the disaster at West Loch was veiled in secrecy and mystery. In particular, the bow of LST-480 is visible as it rusts in the tropical air of Oahu.

CONCLUSION

The attack on Pearl Harbor Dec. 7, the intense salvage activities that followed, the West Loch disaster, and almost 50 years of other natural and cultural processes since the war have contributed to the formation of the underwater archeological record in the study area. This has been a selective history written for a specific purpose: to make those archeological remains more understandable. There are many other facets to the history of Pearl Harbor that weren't discussed and which could be grist for other historian's pens. The preceding, however, should provide a backdrop for the reader who is focused on the fascinating images and facts that have been generated from field activities in this submerged cultural resources study of Pearl Harbor.

CHAPTER III

ARCHEOLOGICAL RECORD

USS ARIZONA

Methodology

The approach used to document the USS ARIZONA and its immediate environment was low-tech and labor-intensive. No one had ever attempted a detailed mapping of a 608-foot battleship in water of 6-foot visibility. There were no guidelines to follow and no black-box technology that could significantly help. Photogrammetry was precluded because of the visibility constraints, shallow water and high site relief. High-resolution sonar mapping techniques are still in the early stages of development.

The most valuable assets at the disposal of the research director were a highly experienced team of NPS survey archeologists and illustrators, and other diving personnel from the park and US Navy. The methodology centered around string, clothespins, measuring tapes and a lot of mapping savvy -- ironically, much of that derived from mapping Pueblo Indian sites in the desert. About half a mile of No. 18 nylon string was laid over the ship to establish straight lines in a world of twisted metal. Lines were marked every 10 feet with numbered plastic clips, forming a kind of "cat's cradle" over the site. The cradle with its measurable lines was first plotted on paper and then, laboriously, the shipwreck measurements followed. Simple trilateration techniques related known points on the marked lines to target features on the wreck.

Each evening all the data acquired during the day were copied onto a master set of drawings. Each morning mylar overlays were made of small sections of the drawing and affixed to divers' slates, who returned to the bottom for additional detail. Divers had a list of required measurements, and they would simply fill in the blanks on each dive. On some dives more than 60 measurements were taken by a two-person team. Thousands of separate measurements were taken during the four weeks spent in the field. An ordinary plastic protractor was used to record changes in angles of the straight lines.

Responsibility for the planimetric view was given to Jerry Livingston and the elevations (profiles) to Larry Nordby. Farley Watanabe and Mark Senning were assigned to the starboard elevation, while Larry concentrated his own in-water time on the port elevation.

To confirm accuracy of critical points along the gunnel and other features of the badly deformed deck, a local survey crew shot targets with an infrared theodolite, or electronic distance-measuring (EDM) instrument. Divers held the reflective mirrors of the EDM motionless on top of a PVC pole, as the bottom was held in place on the feature to be mapped. This proved to be useful in areas where the pole could be stabilized, but was awkward at other points.

A particularly vexing problem developed over the first few days, when the string baseline calculations on the planimetric view repeatedly indicated the gunnels to be several feet wider apart in the bow than was described in the construction plans. This beam measurement was not a detail that should have been altered on ship modifications. We hoped that the infrared theodolite would correct the disparity. To our surprise, the theodolite confirmed the data gleaned from the strings, indicating the ship had expanded at the explosion point, much like an overpressurized tin can. This buckling had not been evident to the divers underwater, whose visual references were compromised by the visibility.

The hull curvature presented other problems for the elevation views. A diver even one body length away could not see the ship, so it was necessary to hand-measure over curves as if they were on a two-dimensional plane. For our purposes, the ship was divided into 10 sections of 60 feet long by the vertical strings from the cradle, creating 20 individual "frames" to be drawn in two dimensions. This approach had one problem: When the whole vessel was pieced together, the scaled drawing was longer than the actual ship. Consequently, the illustrators had to correct each frame to compensate for the two-dimensional depiction of the ship's curved hull. This correcting process was more pronounced on some frames than others, depending on the curvature of each specific section of hull. This was a point in the project where it was highly advantageous to have mappers experienced in rendering cliff dwellings on Southwestern archeological sites. The irregular, three-dimensional features nestled in curving alcove walls of sandstone cliffs provide similar problems for illustrators.

By the time the assessment project began in 1983, low-cost and self-contained color video systems had become commercially available. One of these units was purchased and put to great use in these field operations. The video was capable of recording at least as much as a diver could see in the limited visibility, and was much easier to use in the harbor environment than standard photographic systems. Still photography does not provide instant feedback to the photographer, whereas the color video had a monitor built into the housing that permitted the operator to see exactly what was coming back in "real time." Tricky photographic problems associated with using artificial light in silty water were also reduced by the supplemental use of video.

Perhaps the greatest advantage of video became apparent in the office in Santa Fe months after the field work was completed. Livingston was able to fill in much detail between known map points on specific features by consulting the video tapes. Besides the assistance this provided in the mapping process, tapes resulting from the survey activities proved to be exceptional tools for education, both at the

Figure 3.1 U.S. Navy divers add marked clips every 10 feet to survey line on USS ARIZONA after it was installed by NPS underwater archeologists. (NPS photo by Larry Murphy)

Figure 3.2. Numbered clothespins in upper right hand corner marks a survey point. Diver is sketching feature for inclusion in site map. (NPS photo by Larry Murphy)

Figure 3.3. After being drawn, each feature is measured back to two points on the baseline. This allows accurate mapping through a simple geometric procedure called trilateration. (NPS photo by Larry Murphy)

Figure 3.4. Project Director, Dan Lenihan, records a jog in the survey baseline with a protractor. (NPS photo by Larry Murphy)

Figure 3.5. Farley Watanabe and Mark Senning, rangers from the Arizona Memorial, became proficient underwater mappers during several years of participation in the project. (NPS photo by Larry Murphy)

Figure 3.6. Larry Nordby, NPS archeologist from Santa Fe, brought years of experience in mapping southwestern ruins to the project. (NPS photo by Larry Murphy)

visitors center and on loan to the electronic media. During the active phase of the project, all Honolulu TV channels carried several minutes of the video returns every night for weeks running, and some segments were broadcast on national television.

In addition to rendering architectural drawings of the hull, the team conducted perimeter searches of the battleship to establish the site's extent, inventory the recognizable artifacts where they lay in the wreckage, and mark their positions on the site's base map. The depth of silt around the perimeter of the site was determined by probing with a PVC rod marked in 1-foot increments. All artifacts were left in place, with the exception of items that presented an unacceptable hazard to the memorial that straddles the ARIZONA and through which 5,000 visitors pass each day. Hazardous material included unexploded shells from the 5-inch guns, sacks of congealed gun powder, and corroded high-pressure air or acetylene bottles that were probably used during the salvage activity. The Navy's Explosive Ordnance Disposal (EOD No. 1) team was stationed nearby, and on several occasions they responded to our request to remove such items while the surveyors gingerly exited the water.

Additional studies of the wreck's natural environment were carried out with much greater intensity in 1986, and the methodology is reported in detail in Chapter IV. Those studies included a detailed analysis of the biomass and corrosive properties of the ship, in addition to silt measurements. The technology included manual probes, sampling containers, oxygen probes and a bathycorrometer, which measures galvanic potential of the metal underneath the biofouling crust.

Perimeter surveys to determine the extent of the wreckage field were accomplished using two modes: side-scan technology and divers. Side-scan sonar passes were run in 1983 and again in 1988 using a Klein 100 KHz. A Mesotech side-scan unit used in sector-scan and polar-scan modes was added in 1988. To augment sonar results, dive teams were deployed to conduct 180-degree sweeps that covered the bottom at least 100 feet from the hull remains. The only items divers found were features already noted by the sonar. These features have been incorporated into the site map.

Site Description and Analysis

The ARIZONA (BB 39), a Pennsylvania-class battleship designed for operation in the Pacific, was launched in June 1915. Like most warships, it was built to accomplish specific missions that reflect concepts and strategies operative at the time of design, while later alterations reflect changes in technology and strategies.

The first impression of the ARIZONA is its size -- the vessel is 608 feet long with a beam of 97 feet. The ship was built much bigger than contemporary battleships designed for operation in the Atlantic, which demanded a cruising distance of hundreds of miles, primarily under British, French and German strategies. On the contrary, Pacific operations were conditioned primarily by American and Asian strategies, and required cruising capabilities of thousands of miles. Enormous distances in the Pacific between port facilities, repairs, fueling stations and naval engagements imposed initial design considerations that included speed, reliability, protection, long-range guns, and the ability to carry huge supplies of fuel. Later alterations reinforced one or the other design requirements as a result of changing strategies and technologies balanced against ancient requirements for any seaworthy vessel.

The Naval General Board of 1910 set battleship design parameters for new vessels including the ARIZONA. The ship would have 12 14-inch guns mounted in triple turrets in the main battery, oil-burning engines, "all or nothing" armor, and a speed of 21 knots. Torpedoes and armor-piercing shells were considered the main threats. These specifications would produce some of the fastest long-ranging battleships in the world.

The ARIZONA's armor reflects the interplay between technology, strategy and seaworthy requirements. Armor-piercing shells had to pass through the armor to become armed, and if they passed through ordinary hull or deck plate they would not become armed. Medium armor plate would arm shells, and it offered no protection for the added weight. Only very thick steel plate could offer full protection, hence, the "all or nothing" armor strategy. "All" meant 13.5 inches of steel plate, which is found in areas such as the turrets and armor belt at the water line. If sufficient armor was used all over the vessel topside to thwart armor-piercing shells, the ship would be dangerously unstable. A 3-inch-thick deck was used to ward off most shells and to arm those that passed through. A lower deck was installed of 1.5-inch armor, called the splinter deck, and was sufficient to contain the explosion of shells that passed through the upper deck. The combination provided lightweight, effective protection from most shells.

The ARIZONA underwent a major rebuilding program in 1929-31. Deck armor was increased to 5 inches and an inch was added to the turret tops. The alteration that changed the vessel's appearance was the addition of a steel tank outboard extending from below the turn of the bilge to the top of the armor belt on the side, which is the main deck level. The tank was added to increase torpedo protection. The tank, or torpedo blister, contained an outer void and an inner tank for additional fuel oil. In addition to increased protection from torpedo damage, the blister increased hull displacement, which offset the weight of the added armor, and tripled the ship's cruising range by augmenting fuel capacity. Post-1931 alterations mostly involved upgrade of armament, particularly antiaircraft weapons.

The present appearance of the ARIZONA is a culmination of all the many contributive aspects. The archeological remains are the result of physical changes from alterations during the ship's life, post-attack salvage activites, memorialization and submergence for half a century. A swim over the site starkly reveals these changes and forces a consideration of the history of the vessel and the thinking it represents.

Beginning at the stem of the USS ARIZONA and heading aft, a swimming observer would be struck first with the very sharp lines of the bow. The stem at the hull bottom (forefoot) extends forward of the deck line, creating a bulbous bow form that is covered by silt and not visible to divers. The lines are reminiscent of the iron-clad rams, the precursor of the modern capital ship. The extension is not for ramming, but for additional bow buoyancy and control of the bow wave for efficiency at high speed.

Until reaching the area of heavy damage, which begins to be visible about 40 feet back from the bow around frame 10, the ship does not give the impression of being very large -- the thwartship's dimensions here are less than half those of midship. Damage is slight in this area, the weather or forecastle deck is still in place and various deck fittings, chain, cable and some fairleads are still present. The bull nose is undamaged and both holes are clear of marine growth, much in contrast to the hawse pipes, which are heavily overgrown with marine organisms. The anchors and cable have been removed. The salvage report indicates the anchors were blown clear in the explosion that sunk the ship (Navy salvage record 16 January 1943).

Materials litter the deck. The silt is not very deep and many objects are visible. There are 6-inch chromed pipes laying about that were apparently used to outline the bow during pre-monument memorialization. Steel plates, concrete blocks and a wash basin lie among many unrecognizable metal pieces.

At about 40 to 55 feet aft and 2 feet above the present silt line on the port hull side are rectangular through-hull fittings. Their apparent function, as ascertained from historical photos, is some form of outboard discharge.

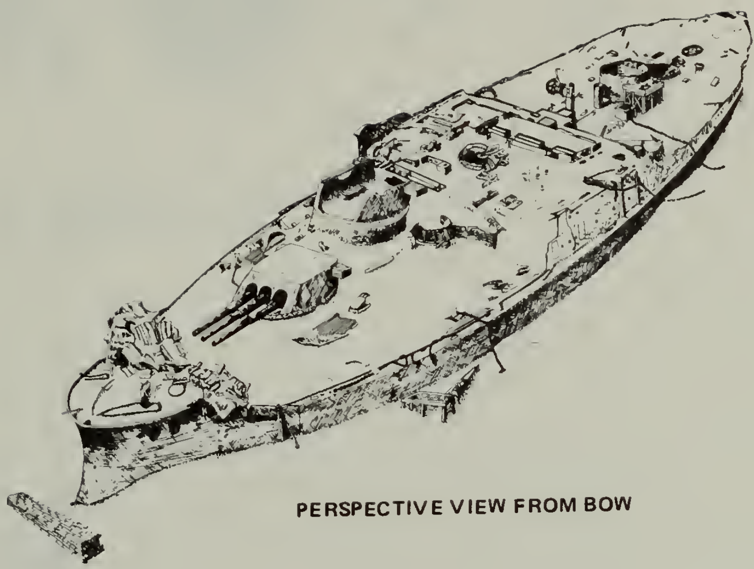
Little damage is evident until one runs directly into the flared metal edges of the major blast zone, where jagged metal of the hull sides is twisted forward and out. Here the midship area is a confusion of twisted bulkheads and deck elements. The survey team discovered a number of live 50-caliber antiaircraft rounds inside the ship under the folds of twisted metal. Toward the port side there are badly twisted and deformed hatch coamings, which indicate the main deck level.

The extensive bow damage is the obvious result of a massive explosion that blew outward and upward. Hull plates are splayed out over 20 feet from the ship's sides. The explosion appears to have occurred deep within the ship, with the main force directed upward, which is expected because of the dampening effects of the water surrounding the hull. The forecastle deck and 5-inch thick main deck are gone. The armor belt, which is at the level of the torpedo blister, apparently helped contain the blast and direct it upward. The forward bow spaces, which are not armored, are relatively undamaged.

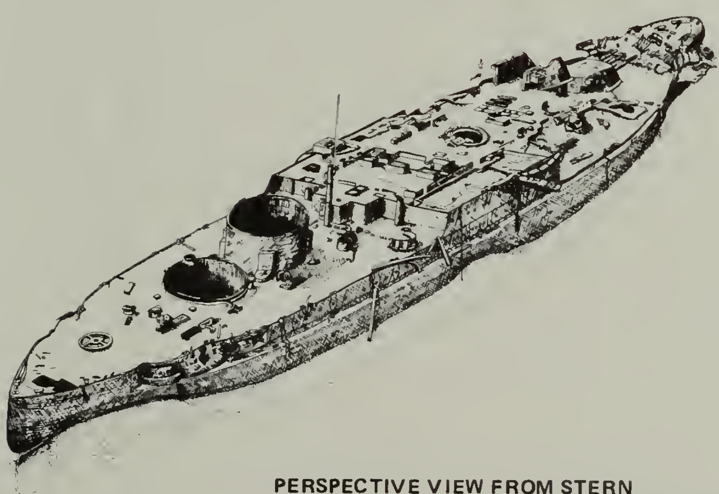
At 70 feet aft, the torpedo blister begins and becomes the dominant feature on the sides; inspection hatches are visible in the blister top. Much of the hull side from gunnel to torpedo blister has been removed by Navy salvage divers, apparently with torches. The Navy salvage record reports much diver cutting between frames 16-24. Evidently the explosion pushed the hull outward above the armor belt. The salvage records indicate metal overhanging the port hull in this area (Navy salvage record 7 April 1943). Scalloped edges from cutting operations are discernible at many points on the wreck. Where there are discontinuities in the hull, it is usually easy to tell if the cause was the blast or intentional salvage actions.

Extensive salvage operations are recorded in the bow area. The remains of the forecastle deck and main deck were cut away and removed, and mud was pumped out of the area. The salvage log records much cutting on the second and third decks and the forward bulkheads. The magazine explosion clearly damaged the lower deck areas aft as far as the No. 2 turret. Navy salvage divers were unable to enter sections of No. 2 because passageways were blocked with wreckage. The explosion apparently collapsed bulkheads supporting the No. 1 turret, which still remains onsite, and the turret rests 15 feet lower than its original position.

On the port side approximately 80 feet and 112 feet aft of the stem, open cracks visible in the torpedo blister continue below the silt line. These cracks in the sides above the silt probably indicate a major structural failure associated with the magazine explosion. In all probability the inner hull and armor belt are also cracked.

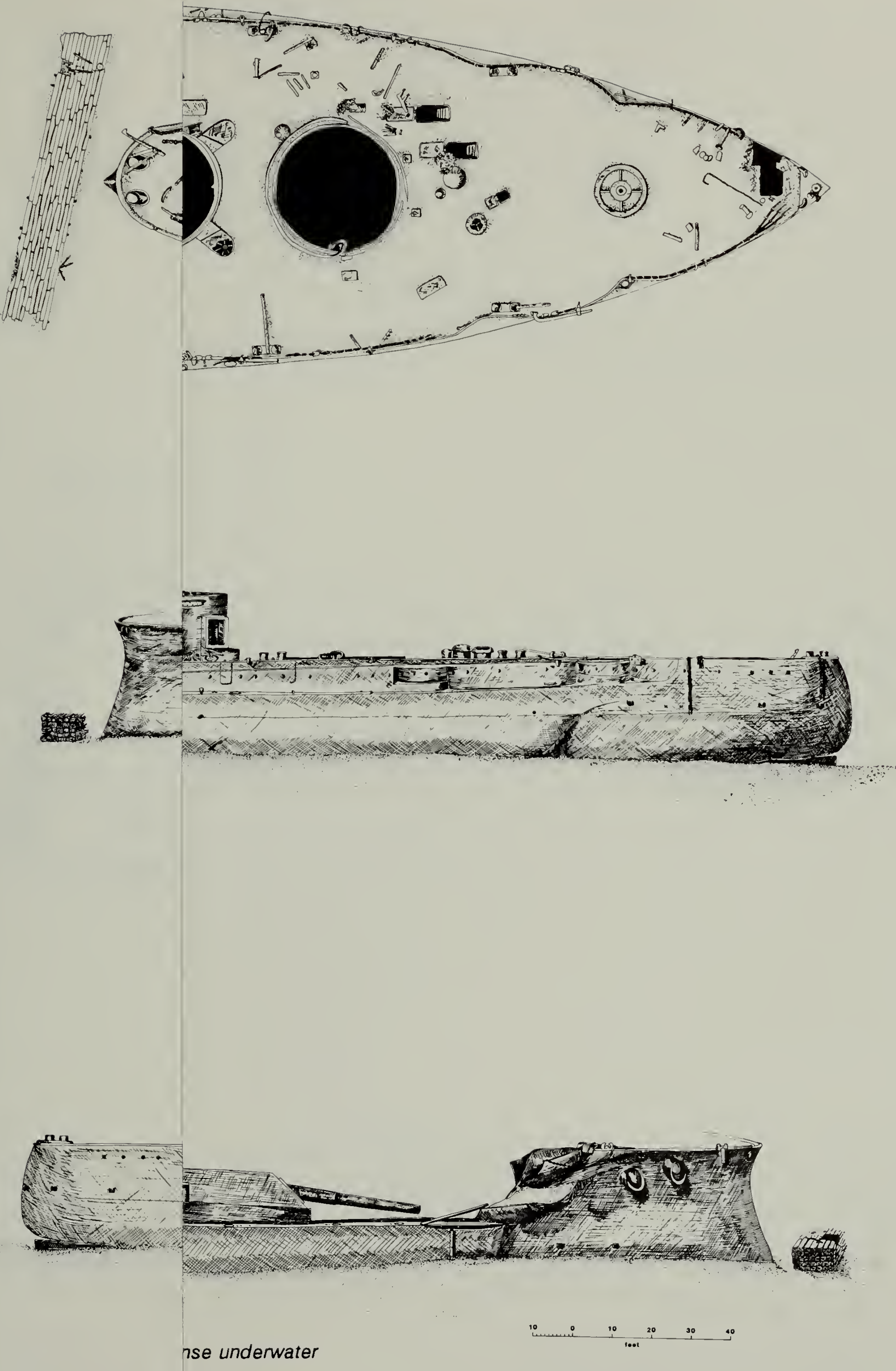


PERSPECTIVE VIEW FROM BOW

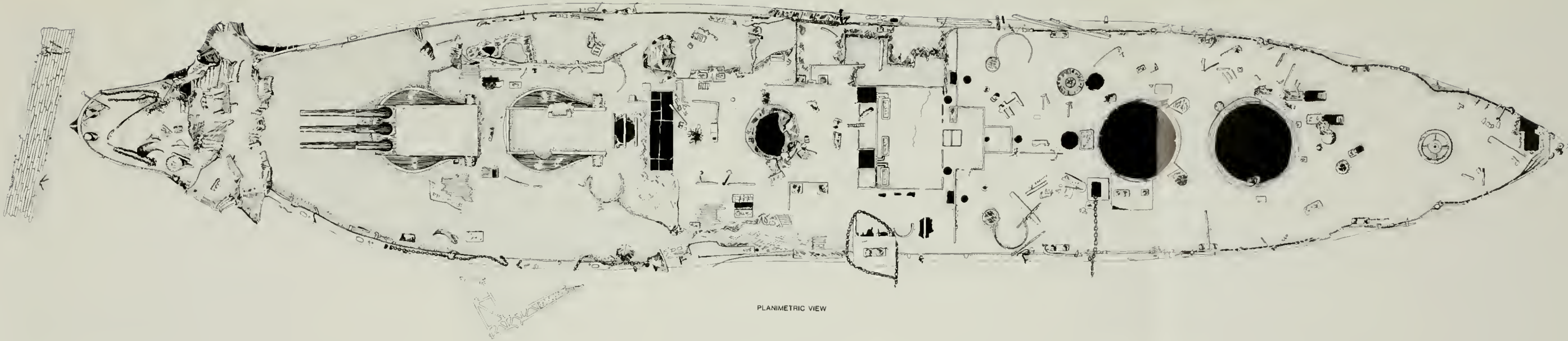


PERSPECTIVE VIEW FROM STERN

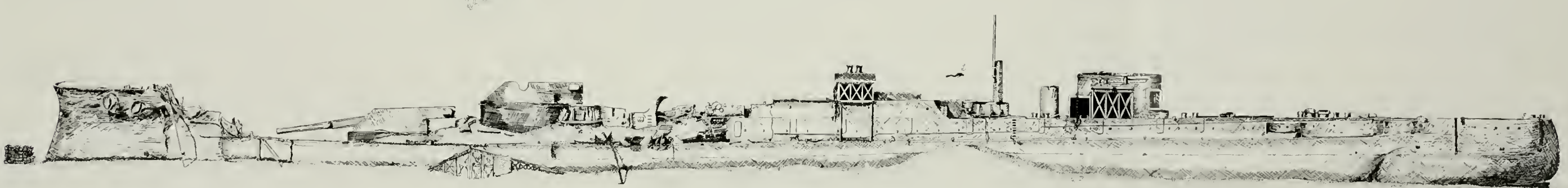
Figure 3.7. *These artistic renderings by Jerry Livingston portray the ship remains from different oblique angles.*



nse underwater



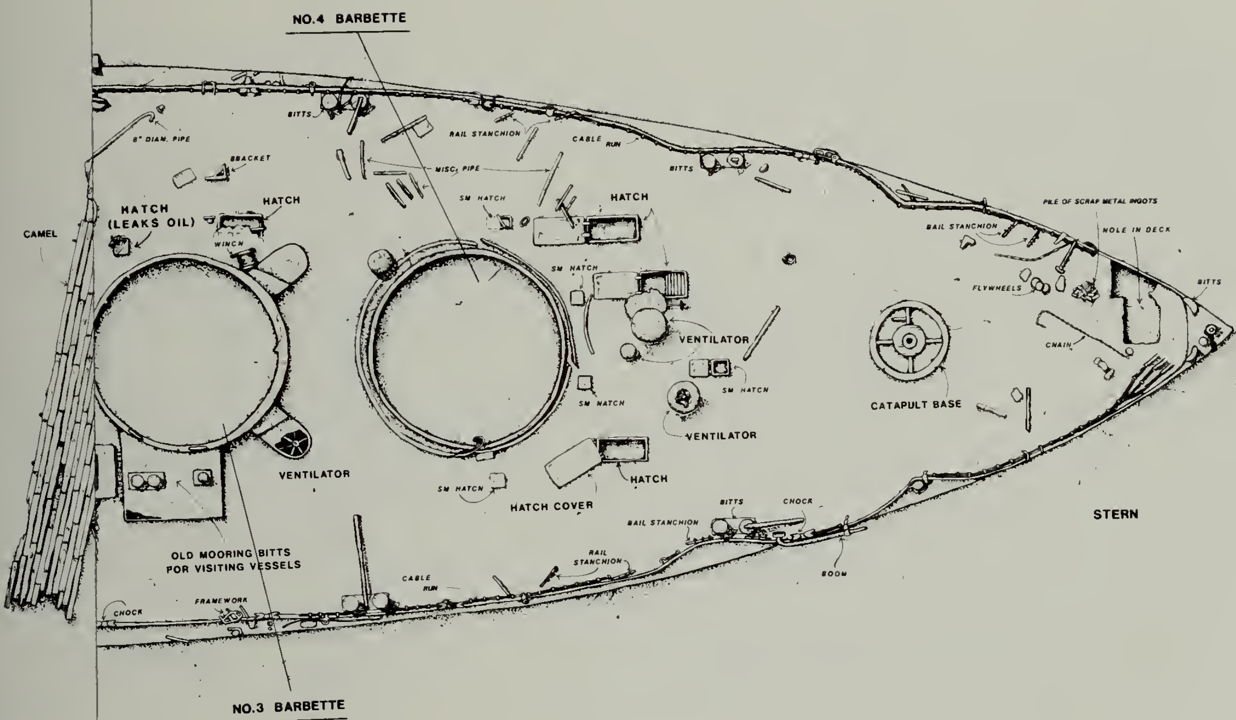
PLANIMETRIC VIEW



PORT ELEVATION

STARBOARD ELEVATION

Figure 3.8.A This set of drawings was developed from data obtained in the intense underwater mapping sessions that took place in 1984.


NO.4 BARBETTE
BITTS
8" DIAM. PIPE
BRACKET
RAIL STANCHION
CABLE RUN
MISC. PIPE
BITTS
HATCH
HATCH (LEAKS OIL)
WINCH
SM HATCH
HATCH
SM HATCH
CAMEL
PILE OF SCRAP METAL INGOTS
BAIL STANCHION
HOLE IN DECK
FLYWHEELS
BITTS
VENTILATOR
CHAIN
SM HATCH
SM HATCH
CATAPULT BASE
VENTILATOR
VENTILATOR
HATCH
SM HATCH
HATCH COVER
BITTS
CHOCK
BAIL STANCHION
STERN
OLD MOORING BITTS FOR VISITING VESSELS
RAIL STANCHION
CABLE RUN
BOOM
FRAMEWORK
CHOCK
NO.3 BARBETTE

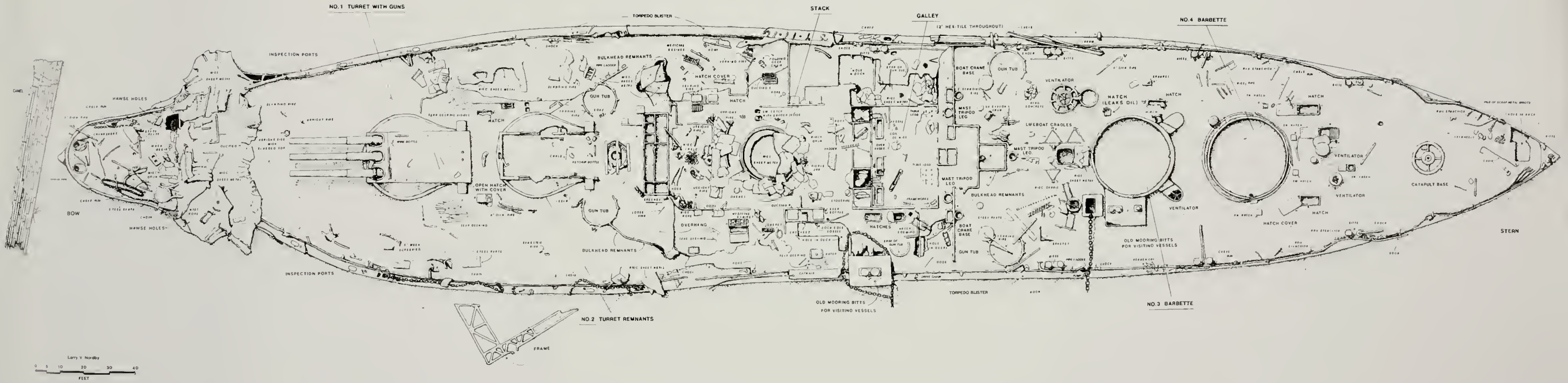


Figure 3.8B Revision of planimetric view by Larry Nordby from 1986 field session.

Figure 3.9. This scale model of USS ARIZONA was constructed by Robert Sumrall using the SCRU drawings shown in Fig. 3.8. (NPS photo by Larry Murphy)

Figure 3.10. Another view of the scale model that now resides in the Memorial Visitor Center. (NPS photo by Larry Murphy)

Figure 3.11. Jerry Livingston, Project Illustrator, working at the muzzles of the 14-inch guns still intact on No.1 turret. (NPS photo by Larry Murphy)

Figure 3.12. Awning cover for a hatch on aft port side of No. 1 turret. (NPS photo by Larry Murphy)

Figure 3.13. Air cylinder protrudes from debris on deck of USS ARIZONA. US Navy EOD divers were called in to rupture the bottle in case it was still under pressure. (NPS photo by Larry Murphy)

Figure 3.14. Intact teak decking is exposed on USS ARIZONA. (NPS photo by Larry Murphy)

Figure 3.15. Entryway to galley and mess area , with bulkheads partially removed . (NPS photo by Larry Murphy)

Figure 3.16. Artifacts in ship's galley area, USS ARIZONA. (NPS photo by Larry Murphy)

Figure 3.17. Coupling of fire hose on deck of ship protrudes through the sediment. (NPS photo by Larry Murphy)

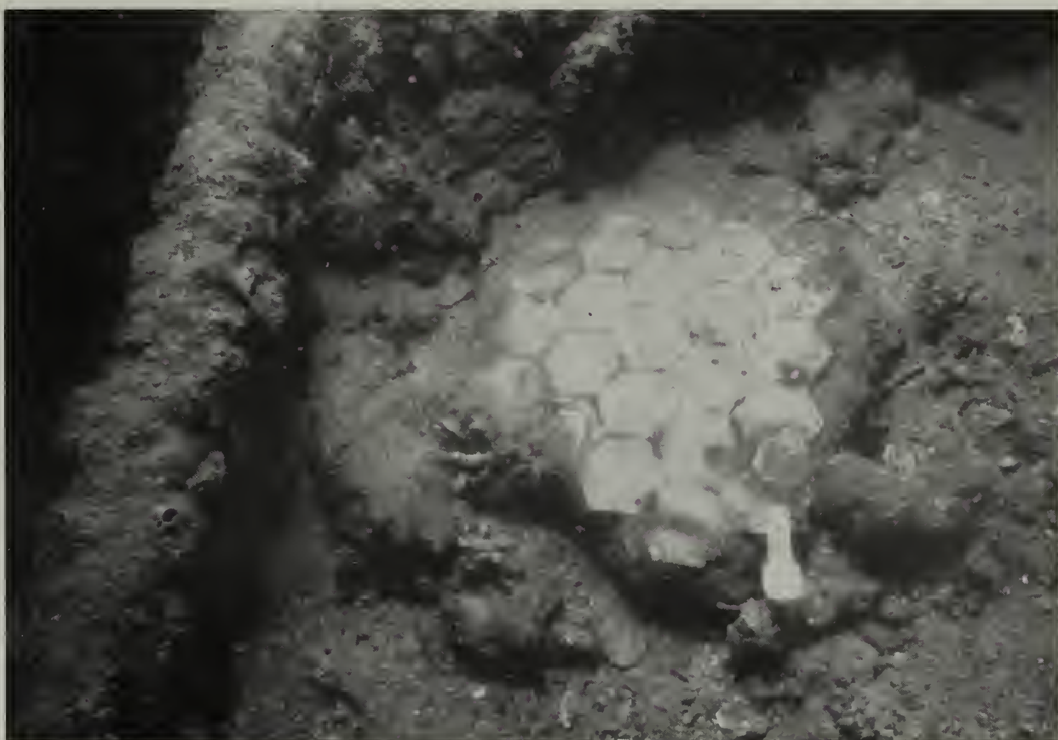


Figure 3.18. Tile floor in galley area of USS ARIZONA. (NPS photo by Larry Murphy)

Figure 3.19. Open hatch on USS ARIZONA with stairwell heavily fouled with marine organisms. (NPS photo by Larry Murphy)

Figure 3.20. Ventilator on deck of USS ARIZONA. (NPS photo by Larry Murphy)

Figure 3.21. Air is trapped between porthole blackout cover and glass on USS ARIZONA. (NPS photo by Larry Murphy)

Figure 3.22. No. 3 barbette protrudes higher than any other feature of the ship. (NPS photo by Larry Murphy)

Figure 3.23. Flagstaff hole at stern of USS ARIZONA. Mooring bitts visible to left. (NPS photo by Larry Murphy)

Along the sides of turret No. 1 below the range finders, teak decking -- the forward remains of the forecastle deck -- is visible after light fanning of the silt. A few feet farther aft on the port side is a hatch that has been propped open for access below decks, probably by the salvage teams (Figure 3.12). The tropical awning support is in place.

Although the guns have been removed from the No. 2 barbette, the turret is in place. The armor plate top was cut off and the embrasures opened to remove the gun tubes, breeches, elevators and other machinery. A gun tub for a 5-inch gun aft of No. 2 turret on the starboard side shows some damage from the explosion or collapse of superstructure, which was subsequently removed in the salvage.

Through the midship forward of the stack, the bottoms of the remaining bulkheads clearly define structural features of the forecastle deck. The boat deck and surrounding superstructure were removed by Navy salvors. Portable artifacts, such as what appear to be medicine cabinets, brackets, electrical fittings and gaskets, are present in this area.

Twisted sheet metal is plentiful in the stack area. Examination and measurement of the deck there revealed no evidence of an explosion, which would have pushed the deck upward. Although it has been frequently reported that a bomb went down the ARIZONA's stack, there is little evidence of an explosion in this area. If a bomb did go into the stack, it apparently did not explode. Most attack-related damage is in the bow area, which supports the contention that the ship was sunk by a bomb or torpedo that sympathetically detonated the foward magazine .

It is the opinion of the researchers that the cause of sinking was a large aerial bomb forward of the No. 1 turret, but this is open to question due to conflicting evidence from an eyewitness. An observer on the stern of the VESTAL, which was moored next to the ARIZONA the morning of the attack, states with great confidence that a torpedo passed underneath the VESTAL's stern and hit the ARIZONA seconds later. Site examination of the ARIZONA port bow reveals no indication of torpedo damage, but it is possible that an entry hole exists farther down in the area buried by silt. There is, however, no sign of buckling of the metal at the silt line or other indications of torpedo damage. To conclusively prove that a torpedo was not involved would require excavation below the silt line. Given the logistics, safety and possible environmental implications of such an operation, it was not possible to definitively resolve the controversy during this survey.

The remains of bulkheads and other features unmistakably define the galley area (Figure 3.15). Doorways, oven bases and what appear to be table legs are visible. The floor was covered with 2-inch hexagonal tile, much of which remains beneath the thin layer of silt. Many artifacts can be found, including coffee cups, plates and silverware (Figure 3.16). The stumps of the main mast tripod legs are discernible, as are the bases of boat cranes.

On the midship port side near the galley area are the remains of an old mooring platform that predates the current memorial. Before construction of the present memorial, launches visiting the ARIZONA would moor to platforms attached to the ship. Heavy stud-link chains extend from this older structure to secure the present boat dock.

Items thrown onto the site from memorial visitors begin to be visible in the galley area. As one moves closer to the memorial platform, unintentionally deposited items appear, including sunglasses, combs, lens caps, and occasionally even complete cameras. Visitors also throw coins, which are periodically removed by NPS personnel involved in site monitoring. The most poignant items are the many flowered leis that are tossed on the ship in remembrance of those still aboard. These leis floating above in the iridescent oil escaping from the ship were a constant reminder of the significance of the ARIZONA to the divers documenting its remains.

Directly under the memorial, the bottom contours on both sides of the ship rise dramatically. This is most probably a function of silt precipitating out of solution due to the effect of the monument's pylons, which extend into the harbor bottom in these areas. Outboard of the starboard side of the ship under the memorial, heavily encrusted flood lamps hang from electrical wires. Although the lamps are all covered with sponges, they appear intact, and were reportedly part of a lighting system from pre-monument memorialization.

Moving inboard, the remains of bulkheads and port gun tubs for 5-inch guns can still be seen. A set of boat cradles is visible. Concrete pieces lie on the deck, probably leftovers from monument construction. Open hatches and ventilators are notable on the deck. The open hatches are partially blocked by marine growth, and the interior of the ship is filled with silt.

A flagstaff has been attached to the remains of one leg of the mainmast tripod at the aft memorial face. The ship's movie projection booth is extant but deteriorating fast, due to the weight of chains that run over it to the dock. Here,too, are items of modern origin dropped from the memorial by visitors, but fewer than on the forward memorial face.

The major changes to the ship aft of the memorial seem to be more the result of Navy salvage than battle damage. The teak-covered main deck was covered forward of the No. 3 turret. All the 14-inch guns have been removed from turrets 3 and 4. An old concrete mooring platform is attached to the No. 3 barbette, which is the largest ship feature above the water (Figure 3.22). Mooring bitts still remain atop the platform.

A few feet from the forward starboard quarter of the No. 3 turret is a hatch opening leaking oil that forms a visible slick on the surface near the memorial. A National Park Service dive team filmed the globules slowly making their way to the surface through a small hole in the deck at the rate of about one every 5 to 10 seconds. How much oil remains in the bunkers cannot be determined without knowing how much was released during the wreck event (no fuel removal is reported in the salvage record log), but with that information it would be possible to accurately determine how much fuel leaks out every day and estimate how much might be left in the ship.

A 12-inch-diameter cable of bundled wire strands can be seen running along the inside of both gunnels in the stern. The function of these cables is unknown, although our original guess that they had something to do with degaussing was not confirmed by military personnel familiar with degaussing technology. The airplane catapult base is visible on the stern. There is a hole in the starboard stern extending to amidships left from the salvage of the airplane recovery crane. On the port stern hull are some portholes that still hold trapped air between the blackout covers and the glass (Figure 3.21); this is the area of the admiral's cabin. The jackstaff hole at the stern is intact, although empty (Figure 3.23).

Moving over the stern, the letters of the ship's name become visible when the biofouling is removed with a wire brush. Swimming under the fantail and down the starboard, one passes a solitary, small blast hole less than a foot in diameter in which an access ladder is visible attached to the forward bulkhead. The top two feet of the rudder protrudes from the silt directly underneath the fantail, but there is no sign of the propeller blades. They are probably still present but entirely covered with sediment. The salvage record log does not mention salvage of the screws.

Site Formation Processes

The initial wreck event and primary deposition of the ARIZONA on the bottom was a straightforward process. It is clear that a major explosion occurred in the forward magazine during the air attack that, besides greatly damaging the forward areas of the ship, caused it to sink. Historical accounts report the ship burned for many days. Sinking most likely occurred bow first, but the shallow water would have precluded a steep angle.

Secondary processes in addition to initial attack damage that have contributed to the present condition of the ARIZONA as an archeological site include salvage operations, corrosion and biofouling. These processes are discussed at length elsewhere in this report -- salvage in Chapter II and natural deterioration processes in Chapter IV. Almost all the ship's superstructure was removed by salvors during the war. To facilitate construction of the memorial the remainder was later removed and taken to Waipio Point, where it still lies.

The natural deterioration of the vessel from electrochemical action has been severe, and some members of the research team who have visited the site frequently over a period of six years are left with the impression that it is progressing more rapidly on the starboard side. Their observations are subjective, of course, and it will probably be several more years into the monitoring process before any quantifiable data will exist to substantiate that observation. Biofouling contributes greatly to the appearance of the vessel, but it is not necessarily contributing to decay of the fabric. Research conducted during the course of this survey indicates biofouling may be inhibiting corrosion (see Chapter IV).

Mechanical action from wind chop and boat wakes also contribute to the formation of the ARIZONA as a wreck site, but their impact has been confined largely to the upper hull areas. The survey team photographed hull plates flexing in the surge during a windy day in 1983 to illustrate mechanical damage. Lying in shallow water increases damage to the wreck because of higher energy and wet/dry tidal cycling. However, the ARIZONA is located in a protected harbor with minor currents, so the destructive processes, though relentless and consistent, are not aggravated greatly by major storms or other climatic events.

Cultural use as a memorial has certain implications for the site; for example, the moorings for boat docks for visitors have involved attaching mooring bits and chains to the vessel. This practice has placed additional stresses on the ship's hull.

If one breaks down the categories of transformational processes of this site into natural and cultural as does Schiffer (1978), it comes clear that the most dramatic effects thus far have been cultural, but the most significant and relentless ones in the future will be natural. Unless humans intervene, the life expectancy of the ARIZONA as a recognizable ship will not span many generations. To date, cathodic protection and other existing technologies do not seem to be reasonable cost-effective alternatives, although intervention as a management option requires staying abreast of developing technologies for submerged structure stabilization.

USS UTAH

Methodology

The UTAH lies on its port side with the deck facing the channel and the keel pointed toward shore. The configuration of the site is considerably different from the upright ARIZONA, a factor that affected the manner it could most effectively be rendered. During the early assessment dives, it was decided to illustrate the site from two perspectives rather than the three-part series chosen for the ARIZONA.

The first perspective would be of an imaginary observer standing on the harbor bottom, eyes even with the centerline of the ship. The second was of an observer standing on the shoreline of Ford Island looking toward the channel; this view is more or less comparable to the starboard elevation of ARIZONA. It is not possible to document the port side of UTAH because it lies in sediment. The hull bottom is also obscured by the sloping shoreline into which it had deeply burrowed during the attempts to salvage the ship.

A series of in-water mapping techniques were used similar to those employed on the ARIZONA, but with some revisions. The starboard gunwale, which protrudes above the water surface, became an imaginary line along which the site was divided into the two illustration views. Reference lines of thin cord were draped over the vessel every 50 feet and marked with plastic clips every 10 feet for reference by the divers, who usually worked in less than 5-foot visibility. Visibility on the site, particularly on the channel side, tended to be slightly less than on the ARIZONA site. At the silt line on the harbor side and at the stern, where the maximum depth reached 55 feet, visibility was less than 2 feet.

The survey lines framed 50-foot-wide hull sections providing known points at every 10 feet. As on the ARIZONA, it was up to the skills of diving artists and archeologists to make sense of a very large, complex fuzzy object.

Like the ARIZONA, some transit shots were made on shallow water points, particularly those areas along the starboard gunnel, which are the highest site elevations. An electronic infrared transit (EDM) was used by the Sea Bees to shoot in a few key points that were in deeper water. Deep-water positioning required construction of a device divers could use to extend the range pole straight up over the point to be surveyed (see Figure 3.24). A line connecting the range pole supported by the innertube was positioned by the divers. Surface swimmers turned the prismatic mirrors toward the EDM.

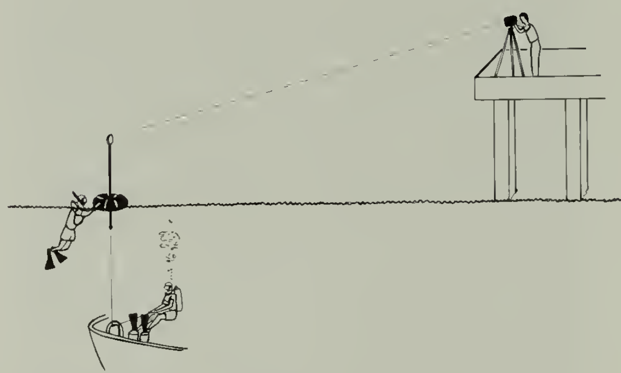


Figure 3.24

Using the combination of labor-intensive hand-mapping coupled with occasional crosschecking by EDM transit, the data acquisition progressed comparably to the ARIZONA. One disadvantage to the UTAH site was the higher relief of deck

Figure 3.25. Pearl Harbor survivor talks with US Navy divers with the remains of USS UTAH in background. (US Navy photo)

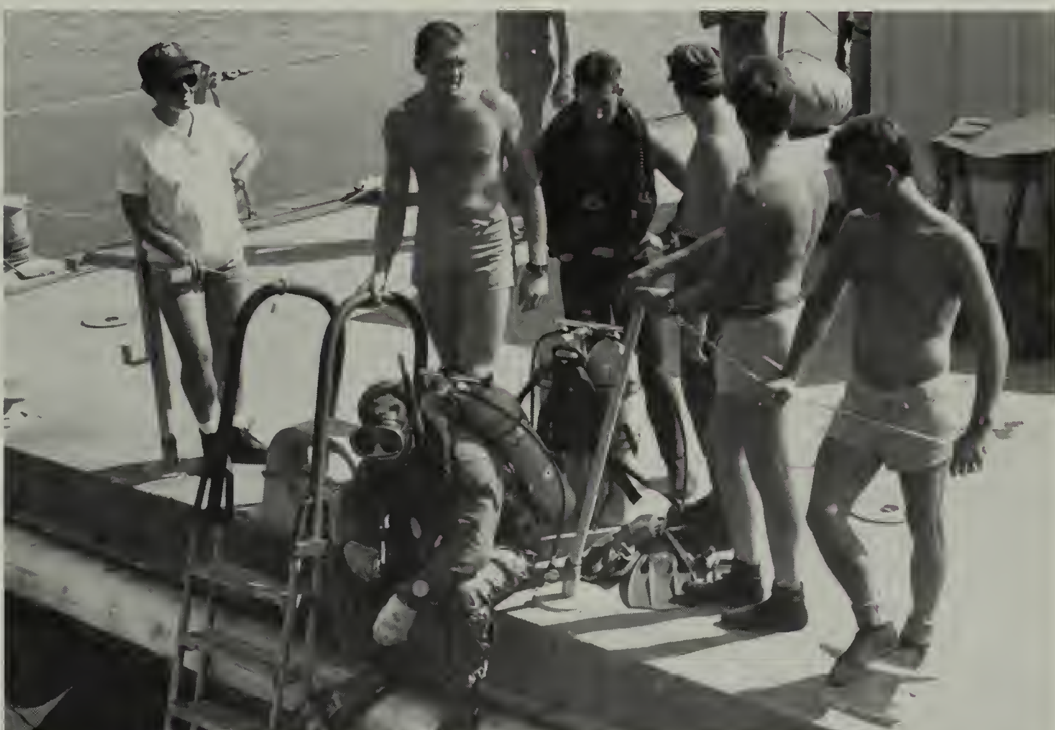


Figure 3.26. Reserve Navy divers from MDSU One (Det 319), Long Beach, California, on work barge at UTAH site. (NPS photo by Larry Murphy)

features, especially in the midship area, which made the trilateration process more difficult. The divers had more trouble stretching the measuring tapes in a straight line between survey points, and the illustrator was forced to back away from the deck to examine high-relief objects, sometimes losing his orientation in the murky water.

One advantage to this site, however, was that the planimetric or "birds-eye" perspective was not required, which eliminated most difficult shallow-water mapping -- an unwelcome task to divers. Even a mild wind chop causes the mapping team, which is bobbing on the surface, to be bounced over sharp metal, and furthermore the light reflecting and refracting off objects only a few feet away can be very disorienting.

Referencing video tape passes on UTAH so that they could be correctly oriented back in the drawing room was difficult. Video tape ended up being most useful for detailing objects along the starboard gunnel, where the camera operator could silhouette against the surface light. Video was also used for adding detail to features once they had been drawn on the site map.

Site Description and Analysis

The USS UTAH (BB31) is located on the opposite side of Ford Island from the ARIZONA. Built in 1909 as one of the first American modern battleships launched after the appearance of the British DREADNOUGHT, the UTAH was rapidly outdated by later battleships like the ARIZONA. The original hull dimensions were a length of 521.6 feet and beam of 88.3 feet. Rebuilt in 1925-26, the vessel was converted to a target ship in 1931 and designated AG-16.

In May 1941 the target ship, which was used for fleet antiaircraft machine gun practice, was fitted with 5-inch guns in single mounts and an assortment of the latest antiaircraft weaponry, including 20mm Oerlikon and 40mm Bofors guns. For carrier-based aircraft practice bombing operations, the UTAH's deck was covered with 6x12-inch timbers, some still remaining on the wreck. Many pilots and gunners were trained with the UTAH and contributed much to later American victories.

The UTAH was sunk by two Japanese aerial torpedoes in 1941. The target ship and the ARIZONA across the harbor are the only vessels from the attack still in Pearl Harbor. The UTAH rolled to port and capsized at its berth after being hit early in the attack, turning 165 degrees from upright, an ironic happening, because the ship with its modern antiaircraft weapons was probably the most able to defend itself from air attack had it not capsized.

Apparently some of the deck timbers shifted as the ship rolled, and obstructed passageways and trapped sailors below decks. Some sailors were removed from the hull with cutting torches as the attack raged. Salvage attempts left the vessel listing to port about 38 degrees with the deck facing the channel and the starboard side facing shore.

The USS Utah Memorial commemorating the loss of ship and men is a 40-by-15-foot concrete platform connected to the northwest shore of Ford Island by a 70-foot walkway. The memorial is about a mile from the Arizona Memorial. A Naval color guard raises the flag each morning to honor the sailors entombed in the UTAH. Although 1.5 million people annually visit the ARIZONA, few have visited the Utah

Memorial; visitation is by special arrangement with the Navy.

As is evident from the site map (Figure 3.27), the UTAH is lying on its port side and partially buried in the silt. A portion of the starboard side area protrudes from the water amidships and is visible from the memorial. It is interesting that some plants have been able to establish themselves on the hulk, and greenery protrudes from unlikely places on the exposed hull portions.

Mechanical damage is an important aspect affecting preservation of the exposed hull. Boat wakes are the source of both mechanical damage and a wide wet-dry zone that contributes to corrosion and weakening. Exposure to air and wave action has heavily corroded the remains above the water surface and made it unable to safely support a person's weight. Harbor tour boats frequent the area, and the Navy often uses an adjacent pier for "touch and go" mooring training of coxswains, so there is considerable traffic in the area.

The exposed hull portion is heavily rusted, but some features are visible. The highest portion visible is a casemate that extends beyond the gunnel, roughly midship. Two circles of bolts are visible above the water, denoting machine gun emplacements. On the forward end of the casemate is a concrete and brass plaque identifying the UTAH. There is a cement covering over the deck that has been broken away. Cement was frequently used to patch damage from practice bombs. Forward of the casemates along the gunnel of the ship a pair of mooring bitts and a chock can be seen. Directly offshore the casemate portion is the rounded corner of the armored bridge.

Perhaps the best way to pursue a descriptive narrative of the current condition of the UTAH underwater is to conduct an imaginary swim from bow to stern, first along the starboard side, and then along the deck (see Figure 3.33 --for reference).

Heading aft on the starboard side, one would probably first see the anchor still secure in the hawse pipe. From here aft there are very few features, except some intact portholes well above the waterline. No signs of war damage are evident, indicating that the torpedo damage on the port side that sank the ship did not vent on the starboard.

The hull is virtually complete and undistorted. Near the starboard bilge line, a hull plate has been removed. A-frame parbuckling gear (or righting headgear) was attached to the bottom of the UTAH during attempts to right the vessel. Cables attached to the parbuckles once led to huge electric winches on shore. It appears that

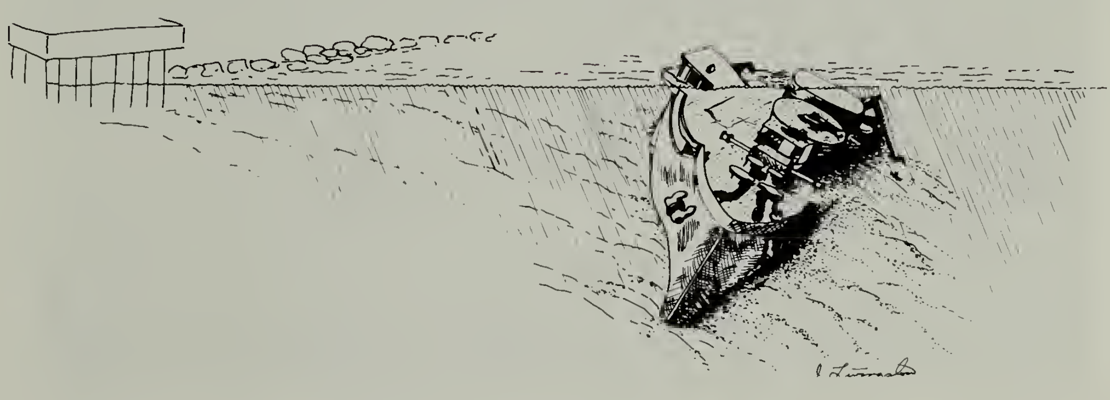


Figure 3.27. Perspective of Utah from bow by Jerry Livingston.

Figure 3.28. USS UTAH looking forward from stern. (NPS photo)

Figure 3.29. USS UTAH looking aft from the bow. (NPS photo)

Figure 3.30. Chock on gunnel of starboard bow of USS UTAH. (NPS photo by Larry Murphy)

Figure 3.31. Stairs lead down into interior of USS UTAH. (NPS photo by Larry Murphy)

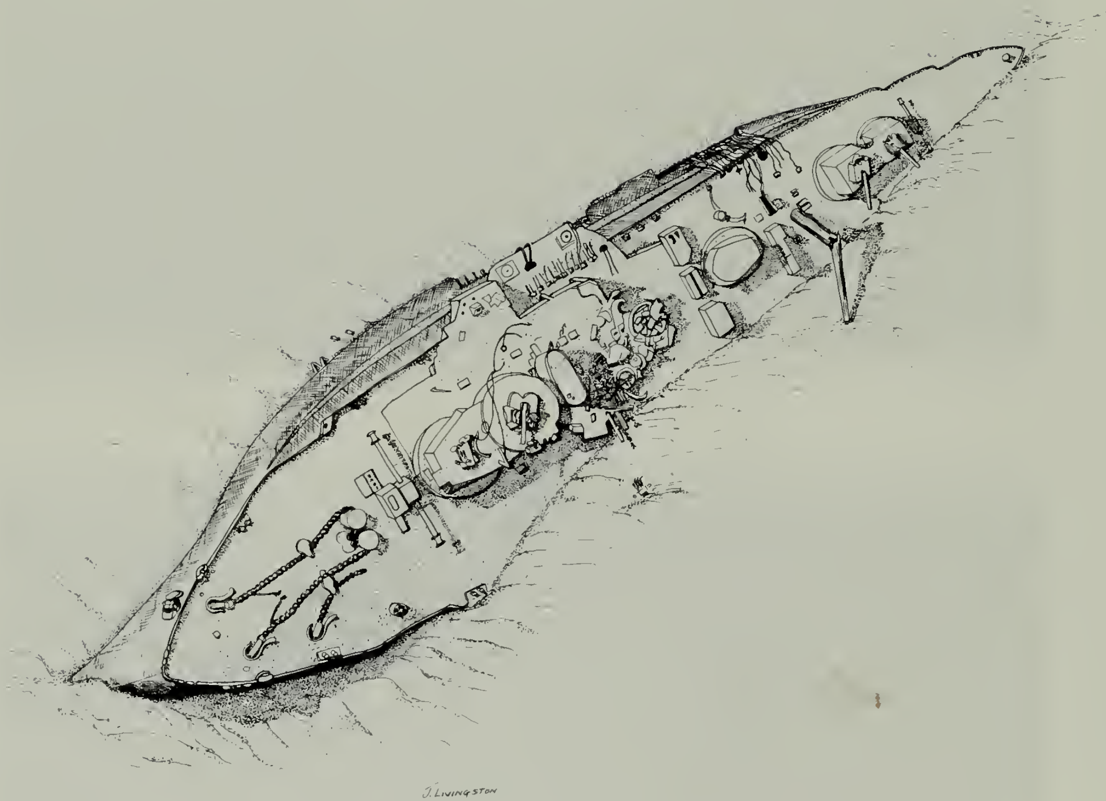
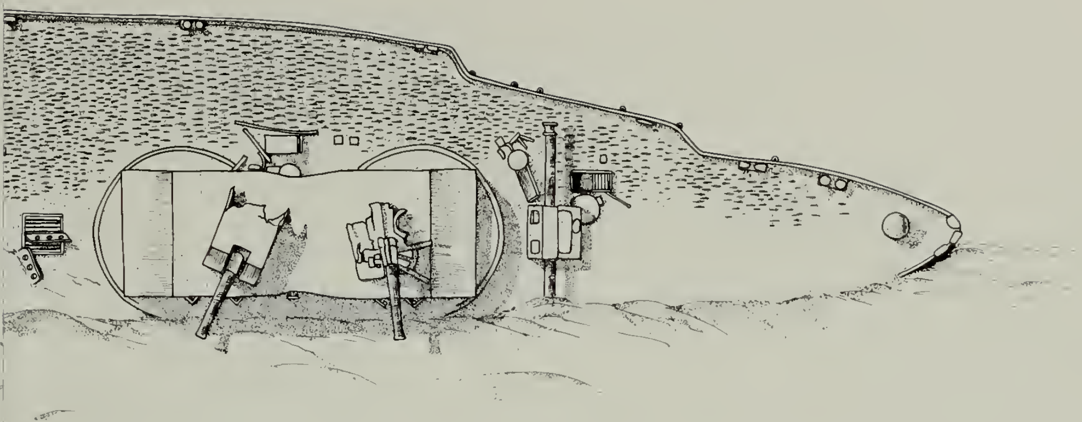
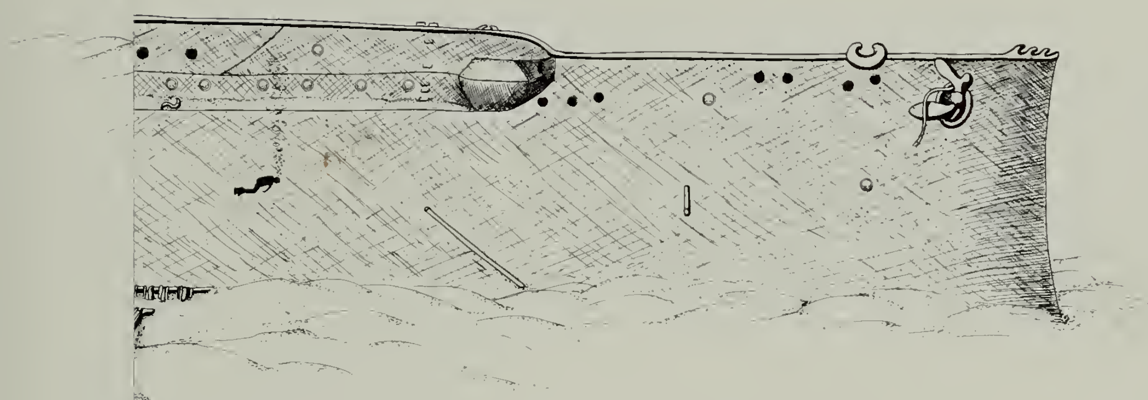


Figure 3.32 Oblique perspective of USS UTAH remains. Drawing by Jerry Livingston.





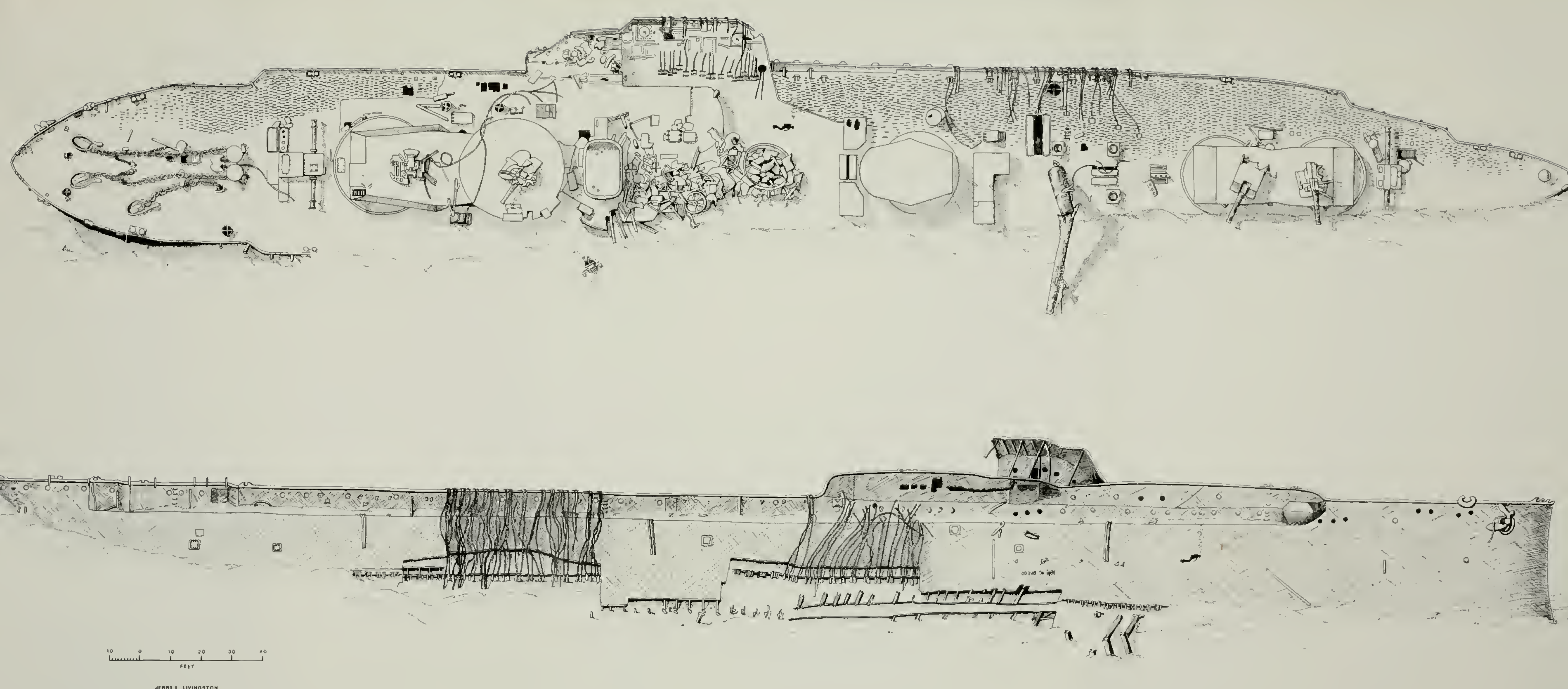


Figure 3.33. Two-part drawings of remains of USS UTAH. Drawn by Jerry Livingston from underwater operations conducted by SCRU and US Navy Reserve MDSU One (Det 319).

at the cessation of salvage activities, the cables were severed and the parbuckle frames cut from the hull. Similar righting operations were successfully conducted on the OKLAHOMA. The UTAH, never righted, was moved sufficiently during the salvage attempt to permit clear access to the nearby pier.

Salvage cables dominate the hull from midship to stern, and bear testimony to the intense effort made by Navy salvage teams to right the ship after it had rolled over during the attack. There are also some salvage patches on the hull toward the stern.

What would be encountered in a swim along the deck of the vessel is much more complex. Beginning at the bullnose and heading aft, one passes over an intact bow area with anchor chains arranged in their leads along the deck and passing through the hawse holes to the hawse pipes, two on the port side and one on the starboard. The stopper cables are rigged and intact. Near the starboard cable is an open hatch with stairs leading down into the hull. The capstans are intact with caps in place.

Aft of the capstans are two more hatches, the port one closed. The starboard hatch is open, and the inner hatch cover with ventilation ports can be seen. Immediately aft of the two hatches is a winch with friction drums that was probably used for mooring.

To the stern of the winch, the elevated superstructure begins. More superstructure remains on this ship than on the ARIZONA. The superstructure was altered during target ship modifications. On the No. 1 turret housing is a bare 5-inch gun mount. The vessel had been outfitted with 5-inch 38-caliber guns in its last refit in May 1941. The forward two are open and near the stem two were enclosed in housings. Atop the No. 2 turret housing is a second 5-inch gun with the barrel in place. Immediately aft and partially exposed is the rounded armored bridge, which served as an observation post during bombing practice.

Amidships and inboard of the exposed casemate lie the remains of the ship's bridge area and main superstructure. The area is a jumble of twisted metal from the damage of sinking and salvage. Recognizable in the wreckage are gun tubs similar to those on the ARIZONA.

Directly below the armored bridge is a 1.1-inch quad antiaircraft machine gun. This new weapon was being evaluated for installation aboard capital ships, like the ARIZONA. They were mounted on the UTAH for training purposes. The barrels of the quad remaining on the UTAH are twisted in various directions. The mount with attached gunner's seat sticks out of the silt and appears to be still attached to the deck.

Behind the stack area aft of the bridge is a raised turret mount. The UTAH had three stern turrets when operating as a battleship. The single-pole mainmast is still in place aft of the No. 3 turret mount, although it is broken. The two sternmost turrets still have 5-inch guns mounted. The housing of the forward gun emplacement is partially intact, that of the aft gun is missing. In a letter from Commanding Officer J.M. Steele to the Commander-in-Chief, Pacific Fleet (December 15, 1941) describing the loss of the UTAH by enemy action, he states that because the UTAH was engaged in bombing target operations

> "all of her 5-inch and 1.1-inch guns were covered with steel houses. All .50 cal. and .30 cal machine guns were dismounted and stowed below decks in storerooms. The ship was covered with two layers of 6x12" timbers for protection against practice bombs. All ammunition was in the magazines and secured. Because of this, it was impossible to make any effort to repel the attack."

It is not clear why the 5-inch guns were not salvaged.

The remains of the UTAH, crisscrossed with many salvage cables on the hull and other evidence of active salvage, portray a sense of defeat and abandonment. Much of the original armament remains aboard -- it is as if the incomplete salvage attempt was declared a failure and abruptly ended. This impression is largely substantiated by the historical documents.

Site Formation Processes

The remains of the USS UTAH as they appear today as an archeological site are conditioned by a series of cultural and natural processes. The immediate traumatic effects of being hit by two torpedoes shortly after 8:00 a.m., December 7, 1941 are not readily visible, due to the port side being deeply buried in the silt. The vessel did turn turtle after the attack, and access holes to free crew members are visible at various points on the hull. Very apparent are the salvage cables attached to the hull that were used in attempts to right the vessel.

For the most part, the cultural processes that were so important initially have become secondary over the years to the natural site-deterioration process. The biofouling and hull corrosion have been intense, and there is a thick layer of sediment covering the majority of the site. Some attempts at memorialzation have left their marks on the ship, but for the most part this is a much more significant issue on the USS ARIZONA. As with the USS ARIZONA, however, it is anticipated that future effects will primarily be from natural rather than cultural origins. The slow but inexorable corrosion of the metal structure accelerated somewhat by wind-generated waves and boat activity will eventually finish the disintegration process of the visible remains.

PEARL HARBOR SURVEY 1988

This joint NPS-USN survey was the first project specifically directed to locating war material underwater related to the 1941 Pearl Harbor attack. Operations included a reconnaissance survey of mooring quays and Japanese plane crash sites within the harbor and a deepwater search for a Japanese midget submarine sunk outside the harbor mouth. A combination remote-sensing and diver visual survey was used to establish whether historic materials remained in priority areas. Priority areas were selected through historical research (Chapter II) and proximity to features associated with the Pearl Harbor attack. Because excavation was not intended, all efforts were directed toward location of visible materials on, or protruding from, the sea bottom.

Personnel

Side-scan sonar operation was by EOD 1 under the command of Capt. Steve Epperson. Field personnel were Lt. Hank Chace, petty officers Dale Alger, Mike Egan and Perry Inman. MDSU divers were under the command of Capt. Dave McCampbell. Liaison and data recording was by Brian O'Conner. NPS personnel were archeologists Dan Lenihan and Larry Murphy; USS Arizona Memorial personnel Bill Dickinson, Dan Martinez and Lisa Dupratt.

Instrumentation and Methodology

Side-scan sonar -- a Klein 521T with a 100KHz towfish coupled with a Motorola Falcon electronic positioning system -- was the basic remote-sensing tool for all operations. A Geometrics 866 magnetometer was towed along with the side scan within the harbor. A Mesotech color video was also utilized during the survey.

Sonar survey procedures followed standardized Navy mine and obstruction detection procedures. Microwave positioning transponder stations were established in the target area vicinity. A search grid was constructed with arbitrary (0-0) geographic coordinates that could be post-plotted by hand into latitude-longtitude, if necessary. A survey block widely encompassing priority crash-site target areas was plotted and divided into 50-meter transects offset from a base line. Each lane was surveyed twice (designated on records as "normal" -- east to west, and "reverse" -- west to east) at a sonar scale of 50 meters and a vessel speed of 2-3 knots, giving 400-percent coverage that provided two directional views of each contact from two adjoining lanes.

Side-scan records were notated by observers and reviewed after completion of all preplotted runs within a survey block. The positioning system and magnetometer computer clocks were coordinated, and automatic event marks representing positioning system updates were recorded on the side-scan record. When a magnetic anomaly was observed, it was noted on the side-scan record, which allowed data record cross-referencing. The combined data allowed a determination of whether a side-scan contact was ferrous metal. In addition, side-scan record areas -- where a magnetic anomaly was present but no obvious contact was visible -- were scrutinized for small contacts that may have been missed by the observer. Contacts selected for diver evaluation were based on signature attributes of size, shape, density and shadow presence. Contacts were selected by the commanding officer of the EOD survey team and an NPS underwater archeologist. A range of targets, including many not fitting expected attributes of structural remains, were selected for diver survey.

Computed plots were generated for all contacts potentially representing items of interest. All necessary corrections for accurate contact location were computed, including towfish layback and slant correction. The Falcon system was used to relocate the contacts so that numbered buoys could be set for in-water evaluation. All selected contacts were bouyed and investigated by a Navy EOD dive team experienced in target location. Diver investigation included systematic grid or circle search and target location with diver-held sonar. Most targets were located within 2 meters of the buoy.

Deepwater side-scan search of the harbor mouth's defensive perimeter was done to locate a Japanese Kohyoteki submarine reported sunk by the USS WARD shortly before the 1941 air attack. The water depth was between 750-1,100 feet (337m), which necessitated deploying the towfish from approximately 3,000 feet of cable. TWR 6 FERRETT, under the command of BMC Allan Connelly, was used for the deepwater search. Two searches were attempted. Deep tows were run at 3.5-3.8 knots, the idle speed of the vessel, with positioning by the Falcon system. The 100m side-scan scale was used. Deployment of the side-scan sensor was difficult because of the length of cable necessary for the depth and the irregularity of the survey area seabottom. It took a lot of complicated coordination between the survey

Figure 3.34. Larry Murphy from NPS SCRU and US Navy personnel from EOD 1 in Pearl Harbor hold side-scan unit used to survey for Japanese aircraft and submarines. (NPS photo by Lisa Dupratt)

Figure 3.35. Monitor of Mesotech sonar used by team for sector, polar and side-scan operations. USS ARIZONA image is emerging from left. Note 14-inch guns of forward turret. (NPS photo by Larry Murphy)

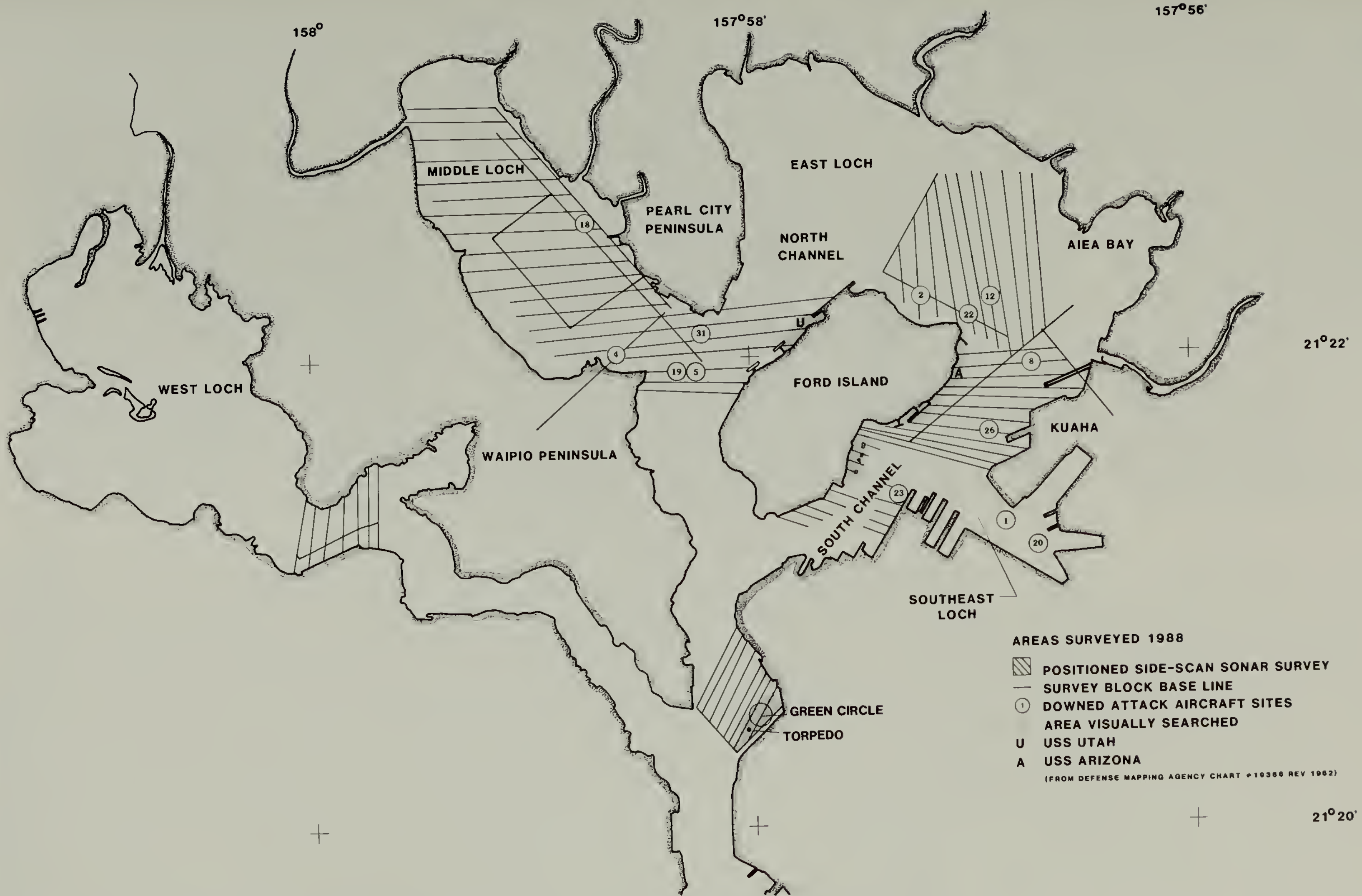


Figure 3.36. Chart of Pearl Harbor and environs depicting historical crash sites and areas surveys in 1988.

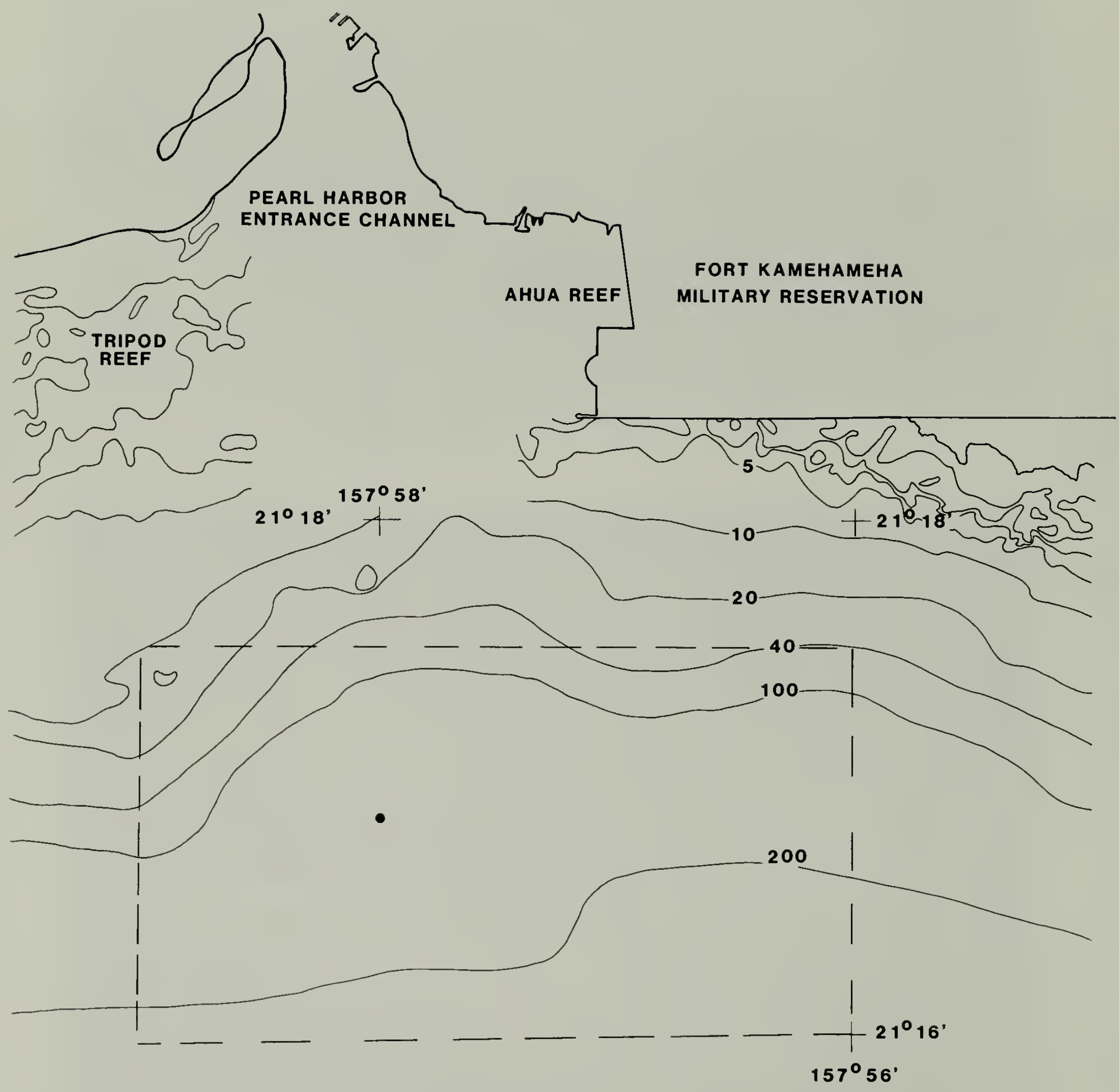


Figure 3.37. Chart of outer harbor defensive zone showing search area and contact location of possible Japanese midget submarine.

team and the helmsman to keep the sonar sensor from hitting bottom.

Unpositioned side-scan survey utilizing both the Klein and Mesotech systems was done in pier areas and also offshore the ARIZONA and UTAH. The objective was to discover materials above the bottom remaining from post-1941 salvage operations. Divers investigated contacts located during this survey.

Visual surveys were conducted directly offshore historic piers and mooring quays within the harbor. MDSU divers were primarily responsible for diver surveys, although an EOD team searched some areas. Diver surveys employed running jackstays to ensure systematic coverage. Jackstay searches utilized two rope base lines between buoy weights. A third rope was incrementally moved between the base lines. A dive team moved back and forth along the third line searching visually and by feel. Any material discovered was buoyed for later documentation and examination by archeologists.

An ROV was also provided by the Navy for the survey. However, equipment failures precluded its effective deployment.

Results

Crash-site priority was determined through historical research by NPS Park Historian Daniel Martinez. Side-scan search areas were designated around historical priority areas, Figure 3.36.

In early June prior to initiation of Project SeaMark field investigations, EOD executed side-scan surveys in five priority crash locations and an area containing materials reported by Navy divers. These areas were dived and the contacts reported:

Site 2: Deep silt, no significant contacts. Divers recovered a piece of aluminum skin that was given to NPS representatives.

Site 22: 100 ft. jackstay search, side-scan ineffective because of shallow depth. Located metal structure believed to be ship-related in 10 feet of water. No other contacts with diver-held sonar.

Site 18: No side-scan sonar contacts.

Site 4: Area of magnetic "deperm" range. No significant contacts. Area reported to have been heavily dredged and all pilings were removed.

Site 12: No significant side-scan sonar contacts.

"Green Circle" site: site location from Navy divers who reported WW II materials in area. Three contacts observed and located by divers: MK 14 torpedo, WW II vintage; metal chair; large hydrodynamically shaped piece of metal, possibly an MSO "pig" used for mine-sweeping.

All these areas except Site 22 and Green Circle site were resurveyed as a part of the large block surveys during field operations in late June 1988. The Green Circle site area searched was expanded by MDSU divers.

EOD divers located a total of 47 contacts observed during side-scan survey operations. No materials conclusively attributable to 1941 activities were located. There were 8 negative contacts; 16 contacts were of natural origin such as ledges, rocks and tree branches; 10 were pipe, angle iron or chain. Other materials identified were: a 55-gal. drum, T-shaped piece of metal, large mass of what appeared to be dumped rubbish, a ship's electric light, a headboard shaped object, a mass of concreted materials including angle iron, flimsy 1 1/2-inch pipe, 10-foot piece of sharp iron, a locker, tapered cylindrical water tank, desk drawer, various sharp metal objects and a safe-like object. One piece of metal that appeared to be of aluminum alloy was recovered in the South Channel. This material, which was turned over to the park, is unidentified and no analysis has been conducted. Southeast Loch has been altered through post war construction. Only unpositioned sonar transects were conducted in this area with negative results.

The diver visual searches were conducted primarily by MDSU, although an EOD team searched portions of the OKLAHOMA pier. Figure 3.36 depicts the area searched. Off pier 5 in 45-50 feet a metal piece and wheel or valve were found and sketched. The muzzle of a 4-inch gun was located sticking up from the bottom off shore Quay F6. Just offshore the OKLAHOMA pier behind Pier 5, large pieces of parbuckle wire were located. In the area of F-6-N a sunken barge was recorded, but little else was encountered.

The area around the ARIZONA was searched but produced little not previously seen by divers during documentation dives. However, an area containing pipe, large metal pieces and a 5-foot- diameter wheel, perhaps a gear, was located just inshore of F-7-S. On the starboard side a large exfoliated plate was discovered. The plate, 12-15 feet long and 6-8 feet wide, is located about 20 feet from the stern. Near F-8-N, just offshore, some wooden pilings were discovered.

Additional jackstay searches were done in the Green Circle site area extending the EOD search area. A 100-by-200-foot area was searched with negative results. Nothing larger than a 55-gallon drum was found. A section along the shore was searched with negative results.

During the unpositioned side-scan surveys in the UTAH area some contacts offshore the wreck were observed. About 40 yards from the hull a 5-inch diameter pipe sticking 10 feet from the bottom was recorded by divers. About 25 yards off the

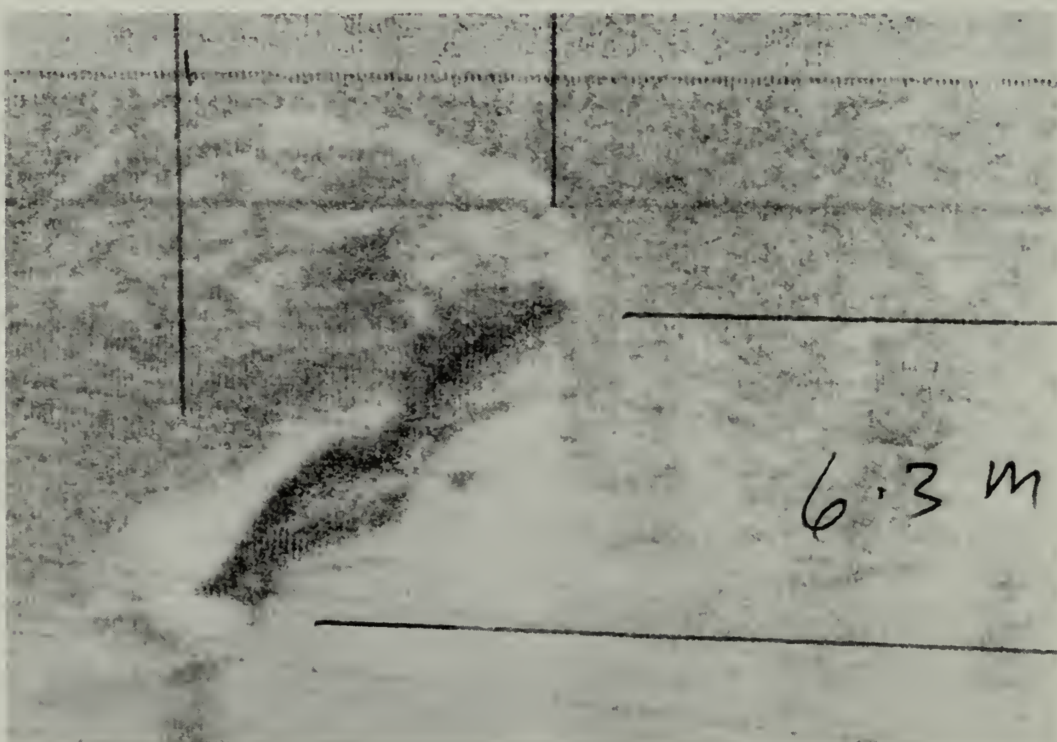


Figure 3.38. Side-scan sonar contact from NPS/Navy survey outside harbor mouth in almost 900 feet of water. (Photo of side-scan record by Mark Hertig)

bow a partly buried box or combination of reinforced plates was found. The plates, together 8-10 feet wide, protruded from the bottom about 6 feet.

During survey operations on July 1, 1988, offshore the Pearl Harbor entrance within the historical defensive perimeter, a sonar contact was made that is a high probability for the Japanese submarine.

The Type A Japanese Submarine had an overall length of 78 feet, beam of 6 feet 1 inch and a draft of 6 feet 1 inch (Jentschura et.al. 1977: 183), with a submerged displacement of 46 tons. The conning tower was approximately amidships (see Figures 2.44 -6).

The probable contact was first made during the execution of track 300 R (west to east) between event marks 10 and 11 on the record and 12 and 13 on the navigation readout at a side-scan scale of 200 meters. Water depth, taken from the chart because no fathometer was available, is 850 feet. The sea bottom appears to be hard sand with few natural objects visible above the sediment. A second view of the contact was obtained on track 320 R at a scale of 100 meters. Both records were produced at 30 lines-per-centimeter. Track 320 was run at an average speed of 4.2 knots, and track 300 at approximately 3.5-3.8 knots. Track speeds were determined by the positioning system.

The contact first appeared at a scale of 200 meters on the starboard channel of the side-scan record about 8 meters (slant range) from the towed sensor. The contact is an anomalous rounded object above the sea bottom. There is an extension of the object observable in the acoustic shadow (white portion) at the approximate center line, which is consistent with target attributes. Because of sensor proximity, the contact appears compressed on the record. The presence of crosstalk (a reflection of the contact) on the port channel indicates the contact is of a highly reflective material, most likely metal. The actual contact can be distinguished from the reflection by the presence of an acoustic shadow, which also indicates the object is above the sea bottom. The height above the bottom is computed to be 3.4 meters or 11 feet (length of shadow = 2.25m; height of fish = 24m; slant range to end of shadow = 15.75m).

A second contact with the object was obtained during a ship track in the same direction as the original contact (west to east), but on a scale of 100 meters. The contact was on the starboard channel, with crosstalk also present on the port channel. The contact appeared in the center of the starboard channel and is minimally compressed. Computations were done to determine the object's approximate length from the signature on the sonar record. A rectangle that represented the contact's linear and cross-track dimensions was drawn on mylar and measured. The linear dimension is 2cm and the cross-track dimension is 1.8 cm, giving an overall length of the contact on the record (computed as the hypotenuse) of 2.69cm. 2.7cm was used for calculations. (Boat speed = 2.1 m/sec, 30 lines/cm, 100 m scale). The computed length of the object is 22.68m or 74 feet.

The sonar contact falls well within the expected parameters for the target. Although nothing can be said for certain without visual confirmation, the contact is congruent with the sonar signature expected from a Japanese midget submarine. Another possibility is a metal-hulled small craft of similar dimensions sunk in the area.

All the evidence indicates the right area, near the right depth for the target of the survey -- a Japanese Type A midget submarine. Visual confirmation either by research submarine or remotely operated vehicle is necessary for further analysis to determine whether this is the target.

CHAPTER IV

BIOFOULING AND CORROSION STUDY

Introduction

Until the joint National Park Service (NPS) and Navy mapping survey in 1983, no major assessment of the USS ARIZONA had occurred since salvage activities after the ship's sinking in 1941. The five-year project contained many facets in its search for information relevant to long-term management of submerged components of the Pearl Harbor National Historic Landmark, especially the USS ARIZONA and the USS UTAH. The July 1986 study examined, among others, one particular aspect of the ship: the role of biofouling in the overall corrosion process. This chapter discusses the methodology and presents the results of that biofouling and corrosion study. Although some comparative data was taken from the USS UTAH, this research focused almost exclusively on the USS ARIZONA.

Our objectives were to: 1) develop a baseline inventory of biological communities and sedimentation extant on structural remains of the ship, and 2) obtain quantifiable measurements of the present state of deterioration of the ship's metal structural elements at various locations (ref. 1). The data gathered would then be used to assess the causes and rates of deterioration of the ship components, and would subsequently provide a scientific basis for making informed decisions regarding the ARIZONA's management and preservation. These objectives do not imply a commitment by federal managers to undertake stabilization of deterioration or in-place preservation (ref. 1).

Several working hypotheses pertaining to the ship's biofouling and corrosion status were formulated prior to the survey to define specific data requirements.

Hypotheses related to vertical ship surfaces were:

1. A layer of hard fouling growth creates anoxic (low oxygen) conditions at the metal surface and reduces the corrosion rate to far below what would occur on a nonfouled surface.

2. The fouling growth (dead and alive) is stable and dense, and forms a relatively

homogenous layer over nearly all vertical areas.

3. Thickness and density of fouling growth is negatively correlated with corrosion rate of the underlying surface.

4. Interior hull and wall surfaces are expected to have lesser areal coverage and thickness of fouling growth, and thus may be subjected to higher corrosion rates than exterior surfaces.

5. Hull components buried in silt exhibit a very low corrosion rate.

Hypotheses related to horizontal (wood and steel) ship surfaces were:

1. A layer of sediment creates anoxic conditions on horizontal surfaces and reduces corrosion and decomposition rates far below those that would occur on uncovered surfaces.

2. The sediment layer is stable and covers nearly all horizontal areas.

3. Corrosion and deterioration of horizontal surfaces are correlated with sediment thickness and porosity.

Two other hypotheses were formulated concerning possible long-term effects on biofouling communities:

1. Nutrient, pollutant and plankton levels will slowly decline in Pearl Harbor as a result of ongoing pollution abatement.

2. Biofouling communities will decrease because of their dependence on the above factors.

Biofouling of Vertical Surfaces

Methods

Sixty-one locations on vertical surfaces were tagged for examination and future monitoring. Vertical stations were generally positioned so that 10 vertical "transects" of three stations each were distributed about evenly over port and starboard sides of the ship (Figure 4.1). Most stations were located on the hull surface, but a few were positioned on typical superstructure surfaces. Depths of vertical stations varied from 7 to 32 feet.

All vertical stations were marked by a 1-foot length of orange survey tape tied to protruding fouling growth. Over a period of several days, it was noted that tape at several locations suffered extensive damage from fish bites. Bites were probably inflicted by balloon fish (Arothron hispidus) that were common around the wreck.

Twelve of the tagged vertical stations were selected as sites for placement of a pair of attachment studs that served as alignment and holding pieces for U-shaped pieces of PVC pipe. Each pipe contained three wire pieces that extended to the fouled hull surface and were used as registration lines for a wire framer on a close-up camera. Each attachment stud consisted of a 6-inch length of 1-inch-diameter PVC pipe glued into a 1-inch PVC flange.

The base of the attachment stud flange was sanded with coarse sandpaper, and the flange was glued onto the hull or superstructure. Splash Zone (trademark name) epoxy was used underwater to attach the studs to the fouling. Initially some studs were glued to shiny hull metal exposed by scraping off overlying fouling and corrosion. However, the epoxy would not bond reliably to the clean metal. Instead we found that the hard, dead fouling surface (where the top layer of soft living fouling had been scraped away) was a much better bonding substrate for the studs, so subsequent attachments were made to hard fouling.

Corrosion and biofouling material, scraped from areas where attachment studs were to be glued, was collected by a diver

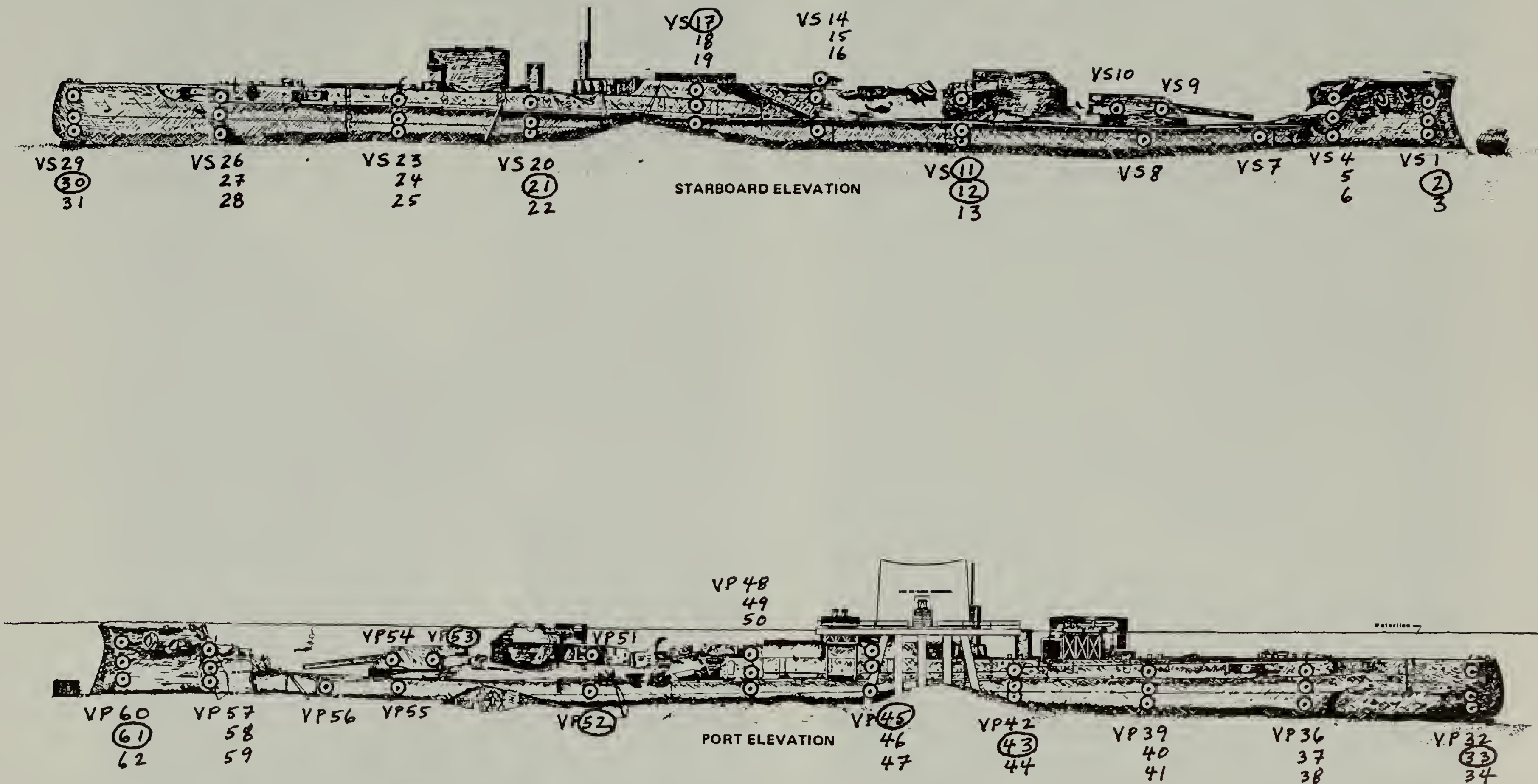


Figure 4.1. *Locations of vertical surface biofouling stations on the USS ARIZONA. Encircled station numbers denote permanently emplaced PVC studs for photo monitoring.*

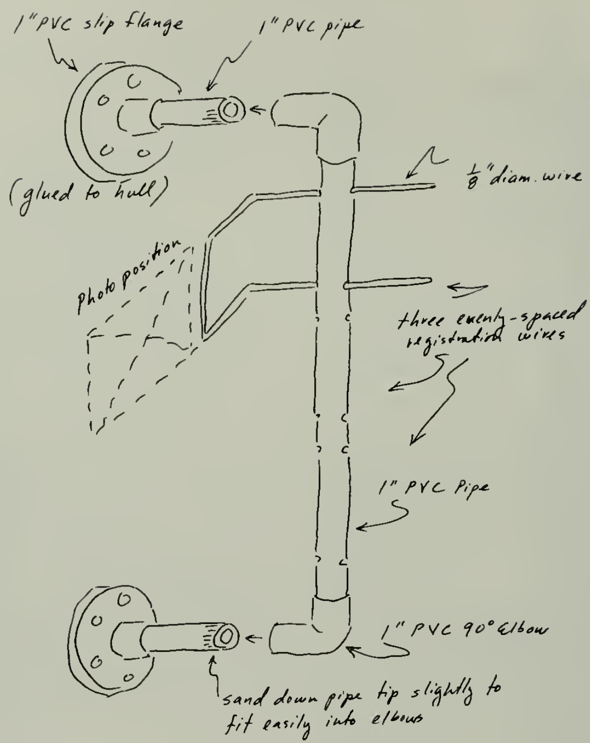


Figure 4.2. *Diagram of photo alignment bar.*

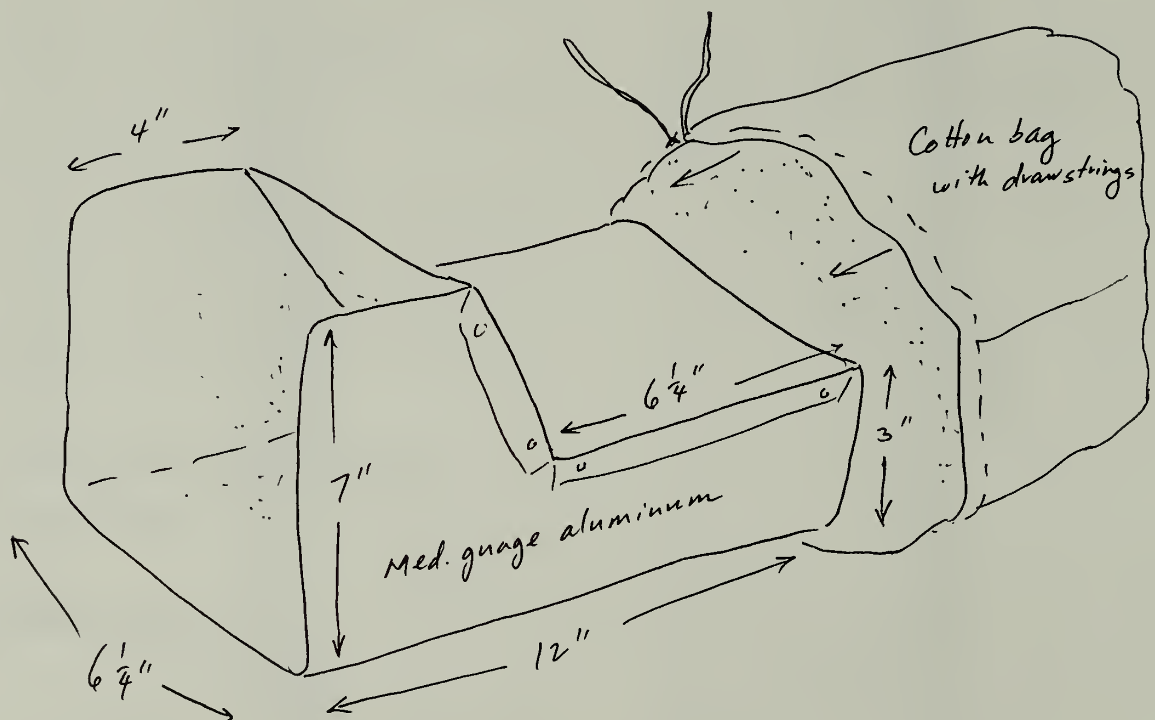


Figure 4.3. *Diagram of bioscraping collector funnel.*

Figure 4.4. Corrosion and biofouling material being scraped into collection funnel by divers. (NPS photo by Larry Murphy)

Figure 4.5. Thickness of corrosion and biofouling was measured at selected sampling stations on USS ARIZONA. (NPS photo by Larry Murphy)

holding a metal funnel-like device under each area as material was scraped off. That material was funneled into a cloth bag and frozen until later analysis. In the laboratory, scraped material was dried in an oven at 100 degrees Centigrade for about eight hours, until it yielded dry weights of fouling and corrosion components. Most of the corrosion products were separated from biofouling with a bar magnet. Each area scraped measured 6 inches across and 6 inches down (36 inches square).

Several days after the PVC attachment studs were glued in place, three photos were taken at each photo station using the alignment/registration bar. The area of each photo measured 5.5 inches wide by 3.5 inches high, and the vertical distance between each photo was about 4 inches. Photos were taken with a Nikonos underwater camera, 3:1 close-up extension tube with framer, strobe flash and ASA 64 slide film. Photo slides were later projected onto a screen, and the resultant images were used to identify and estimate the approximate percent-per-area coverage of dominant fouling organisms. Photo station locations are indicated in Figure 4.1 as encircled station numbers.

A pair of divers visited all vertical stations and made measurements and observations pertaining to biofouling. To ascertain fouling thickness, a pointed 5/16-inch steel rod was driven through the fouling until solid substrate was encountered. Fouling thicknesses are reported as two values: the first being the thickness of hard/dense, generally dead fouling, and the second being the estimated average maximum thickness of living fouling. Estimates were also made of percent coverage or presence/absence of dominant, easily identified fouling organisms such as vermetid mollusks, oysters, bryosoans, tube worms, sponges, tunicates and algae.

Results

Approximately 25 common taxa of fouling organisms and 25 common species of fish were observed near the ship (Table 4.1). The checklist of organisms includes only macroorganisms that were readily identifiable and that collectively comprised more than 90 percent of the living biomass on or near the ship. The limits of time and survey resources excluded the inventory and identification of organisms that were rare, microscopic or cryptic in nature. Such organisms probably contribute little overall biomass or stability to the fouling communities and are only minimally relevant to the ship's corrosion.

Ten taxa of fauna and five taxa of flora comprised the bulk of fouling observed on vertical hull and superstructure stations (Table 4.2). A combination of dead and live fouling covered an estimated 99 + percent of all surface area around all vertical stations. Zonation of organisms was evident, with maximum diversity and abundance of animals occurring in areas of higher water motion, such as in shallower depths and near the ship's bow and stern. In particular, the abundance of biofouling -- such as sponges (especially erect forms), foliaceous form of Schizoporella errata (bryozoan), large feather-duster worms, and Salmaoina dysteri (sagebrush tube worm) -- decreased with depth and the greater coverage of diatom/detritus mat. Vertical surfaces near the bottom (at depths of about 28 feet or more) were generally covered by a high percent of diatom/detritus mat and Branchiomma cingulata (colonial feather-duster worms).

Although vermetid mollusks and oysters were not observed at some vertical stations, it is likely they were present at the majority of those stations but not readily visible because of coverage by encrusting

Table 4.1. Phyletic checklist of common organisms observed on USS ARIZONA.

Plant Kingdom

CYANOPHYTA (Blue-green Algae) -- film and filamentous blue-green algae
CHLOROPHYTA (Green Algae) -- filamentous green algae
CHYSOPHYTA (Golden-brown Algae) -- primarily diatoms in diatom/detritus mats
RHODOPHYTA (Red Algae) -- filamentous red algae

Animal Kingdom

PROIFERA (Sponges)
- Several "encrusting" species in the following colors: tan, grey, black, white, orange, pink, green, yellow and blue.
- Several "erect" species including a pink form, light- blue rounded form, and a black "finger" sponge.

CNIDARIA (Coelenterates)
- Hydrozoa
  - Hydroida
    - Pennairiidae
    - Pennaria tiarella (Feather hydroid)
  - Anthozoa
  - Telestidae
    - Telesto riisei (Orange soft coral)
- Actinaria
  - Aiptasiidae
  - Aiptasia pulchella

ANNELIDA (Segmented worms)
- Polychaeta
  - Sedentaria
    - Sabellidae
      - Branchiomma cinqulata (Colonial feather-duster worm)
      - Sabellastarte sanctijosephi (Feather-duster worm)
    - Serpulidae
      - Hydroides spp, (Tube worms)
      - Salmacina dysteri (Sagebrush tube worm)

ARTHROPODA (Arthropods)
- Crustacea
  - Cirripedia
    - Balanidae
      - Balanus spp. (Barnacles)
  - Decapoda/Natantia
    - Alpheidae
- Alpheid spp. (Snapping shrimps)

Stomatopoda
Squillidae
Squilla sp. (Mantis shrimp)
MOLLUSCA (Molluska)
Mesogastropoda
Vermetidae
Vermetus alii (Vermetid worm)
Bivalvia
Pteroida
Isognomidae
Isognomon spp. (Flat oysters)
Ostreidae
Ostrea spp. (Native oysters)
Anomiidae
Anomia nobilis (Saddle oyster)
Myoida
Pholadidae
Martesia striata (Wood-burrowing bivalve)
Teredinidae
Teredinid spp. (shipworms)
ECTOPROCTA (Moss Animals)
Gymnolaemata
Ascophora
Schizoporellidae
Schizoporella errata (Encrusting bryozoan)
CHORDATA (Chordates)
Urochordata
Ascidacea
Didemnid spp. (Colonial tunicates)
Unidentified colonial tunicates, several species
Unidentified solitary tunicates (Sea squirts), several species
Vertebrata
Osteichthyes (Bony Fishes)
Aguilliformes
Muraenidae
Gymnothorax sp. (Moray eel)
Perciformes
Kuliidae
Kuhlia sandvicensis (Silver bass)
Priacanthidae
Priacanthus cruentatus (Glass eye)
Apogonidae
Apogon spp. (Cardinal fish)
Carangidae

Caranx melampygus (Jack, Papio)
Mullidae
Upeneus arge (Goat fish)
Mulloidichthys samoensis (Goat fish, Kumu)
Chaetodontidae
Chaetodon auriga (Gold butterfly fish)
Chaetodon lunula (Raccoon butterfly fish)
Chaetodon ephippium (Butterfly fish)
Pomacentridae
Abudefduf sordidus (Sordid damsel fish)
Abudefduf abdominalis (Sergeant Major, Mamo)
Mugilidae
Mugil cephalus (Mullet)
Labridae
Cheilio inermis (Mongoose fish)
Scaridae
Scaridae spp. (Parrot fish)
Gobiidae
Psilogobius mainlandi (Burrow goby)
Bathygobius fuscus (Goby)
Eleotridae
Asterropteryx samipunctatus (Burrow eleotrid)
Acanthuridae
Acanthurus dussumieri (Surgeon fish, Palani)
Acanthurus xanthopterus (Surgeon fish, Pualu)
Acanthurus mata (Surgeon fish, Pualu)
Zebrasoma veliferum (Sailfin tang)
Naso brevirostris (Unicorn fish)
Naso unicornis (Unicorn fish, Kasla)
Tetraodontidae
Arothron hispidus (Balloon fish)

Table 4-2 Composition and thickness of fouling at vertical hull and superstructure stations.

Key: % = % areal coverage
* = photo station
#/m² = no. of individuals per square meter

abun = abundant (% areal coverage given if greater than 20%)
pres = present in low abundance
com = common
b/g = blue-green; grn = green

Station	Water Depth (ft.)	Sponges encrust.	Sponges erect	Schizo-porella	Annelids *Branchiomma*	Annelids lg. Sabellids	Annelids *Salmacina*	Mollusks Vermetids	Mollusks Oysters	Tunicates Solitary	Tunicates Colonial	Diatoms/ detritus	Algae	Fouling Thickness (in.)
VS 1	12	65%	10%	5%	com	5/m²	1%	com		15/m²		10%		.75-2.5
2*	22	65%	10%	5%	com	5/m²	1%	com		10/m²		20%		1.0-3.0
3	28	55%	10%	3%	com	5/m²	1%	com	pres	10/m²		25%		.75-2.5
4	12	45%	5%	5%	pres	4/m²		com	pres	10/m²		10%		1.0-2.5
5	25	45%	5%	5%	pres	4/m²		com	pres	10/m²		15%		1.0-2.5
6	30	10%		1%	com				pres	20/m²		10%	red 80%	.75-3.0
7	30	10%		1%	com				pres	20/m²	1%	35%		.75-3.0
8	32	10%		1%	com				pres	40/m²		35%		.75-2.5
9	21	10%			abun(50%)				pres	12/m²		90%		.75-2.0
10	20	10%	2%		abun(50%)			pres	pres	12/m²		90%		.75-2.5
11*	13	20%	7%	1%	pres	2/m²		pres	pres	15/m²		20%	b/g 7% red 10%	.75-2.0
12*	27	25%	5%	2%	com	1/m²		com		10/m²		15%	b/g 7%	1.0-3.0
13	31	20%			abun(50%)					5/m²		90%		1.3-3.0
14	7	20%	5%	1%	pres	10/m²		com				20%		.63-2.0
VS 15	16	20%	20%		pres	10/m²		pres	pres	5/m²		20%		1.3-3.0
16	28	25%			abun(40%)	3/m²						75%		1.0-3.0
17*	8	15%	5%	15%	pres	10/m²				5/m²		20%	b/g 7%	.75-3.0
18	17	15%	10%	1%	pres	10/m²		pres	pres	20/m²		30%	b/g 5%	.50-2.0
19	23	40%			pres					10/m²		90%	red 40%	1.0-3.0
20	14	60%	15%	1%	pres	30/m²		pres	pres	10/m²		40%		1.0-3.0
21*	22	30%	10%	2%	pres	1/m²		pres	pres	5/m²		50%	red 10%	1.0-3.0
22	28	10%	5%		abun(30%)				pres			90%		.75-3.0
23	15	75%		2%	pres	10/m²		com		12/m²		20%		1.5-3.0
24	23	70%		2%	com	1/m²		pres	pres			20%		.75-3.0
25	28	10%	5%		abun(80%)				pres			90%		.75-3.0
26	17	40%	5%	1%	pres	15/m²				15/m²		20%		.75-3.0
27	24	25%	10%	4%	pres	5/m²						25%	red 20%	.75-3.0
28	29	10%			abun(40%)			pres				90%		.75-3.0
29	17	30%	20%	5%	pres	1/m²		abun	pres	5/m²		20%		2.0-4.0
30*	27	40%	5%	10%	pres	1/m²		pres	pres	10/m²		15%	red 60% grn 2%	.75-3.0
31	32	30%			abun(40%)	3/m²				100/m²		50%	red 20%	

Table 4.2. *(concluded)*

Station	Water Depth (ft.)	Sponges encrust.	Sponges erect	Schizo-porella	Annelids *Branch-iomma*	Annelids lg. Sab-ellids	Annelids *Salma-cina*	Mollusks Verm-etids	Mollusks Oys-ters	Tunicates Soli-tary	Tunicates Colo-nial	Diatoms/ detritus	Algae	Fouling Thickness (in.)
VP 32	17	75%	10%	2%	com	10/m^2	1%	com		10/m^2		15%		.50-2.0
33*	28	25%	20%	2%	com	1/m^2		com		30/m^2	2%	15%	grn 15%	.50-2.5
34	32	5%	5%	1%	abun(75%)	4/m^2		com		10/m^2		10%	red 40%	.75-2.0
36	17	15%	15%	5%	pres	5/m^2	1%	abun		12/m^2		20%	red 50%	.75-3.0
37	24	70%	10%	10%	com	15/m^2		pres		12/m^2		40%		.75-2.5
38	32	20%	30%	5%	abun(50%)	3/m^2		pres		20/m^2		50%		1.0-2.5
39	17	50%		10%	com	10/m^2		com		12/m^2		25%		.75-3.0
40	26	20%	5%	1%	pres	12/m^2		pres		15/m^2		60%	red 25%	.75-3.0
41	31	20%		1%	abun(60%)			pres		50/m^2		90%	red 20%	.75-3.0
42	18	50%			pres	3/m^2		pres	pres	10/m^2		40%		1.0-3.0
43*	24	50%	5%	2%	pres					5/m^2		40%	red 10% grn 3%	1.0-3.0
44	29	10%			abun(60%)					20/m^2		90%		.75-2.5
45*	9	40%	10%		pres	8/m^2		com		50/m^2		30%	red 15% b/g 5%	.75-3.0
46	14	30%	10%	1%	pres	5/m^2		pres		20/m^2		50%		.75-3.0
47	27	5%			abun(50%)			pres		5/m^2		80%		.75-2.5
48	10	50%	5%	5%	pres	10/m^2		abun		10/m^2		15%	red 20%	.75-3.5
49	18	50%	5%		abun(20%)			pres	pres	30/m^2		80%		1.0-3.0
VP 50	27	1%			abun(20%)			pres	pres	30/m^2		80%		.75-3.0
51	12	20%	5%	10%	pres	10/m^2		com				5%	red 20%	1.5-3.5
52*	28	5%	2%	1%	abun(40%)			pres		30/m^2		50%		1.0-2.5
53*	17	5%	2%	1%	abun(80%)	5/m^2	1%			15/m^2		90%	b/g 1%	.75-3.0
54	17	5%	2%	2%	abun(80%)		1%			15/m^2		90%		.75-3.0
55	28	10%	3%		abun(80%)			pres		20/m^2		40%		.75-2.5
56	27	5%			abun(75%)			pres		5/m^2		70%		1.0-3.0
57	11	50%	15%	2%	pres	5/m^2	1%	com		100/m^2		10%		.75-3.0
58	18	75%	12%	1%	pres	25/m^2		com	pres	100/m^2		20%		.75-3.0
59	24	25%	10%	1%	abun(50%)			com	pres	100/m^2		25%		1.0-3.0
60	10	50%	10%	15%	pres	5/m^2	1%	pres	pres	100/m^2	1%	10%		.75-3.0
61*	17	70%	10%	5%	com	5/m^2	1%	pres	pres	100/m^2		30%		.75-3.0
62	27	10%	5%	1%	abun(80%)		1%			5/m^2		90%	red 30%	.75-3.0

Table 4.3. *Water depths (in feet), hard fouling thickness (in inches) and dry weights (in grams per 36 inches square) of scraped corrosion product and fouling growth for photo biostations on USS ARIZONA.*

STATION	WATER DEPTH	HARD FOULING THICKNESS	DRY WEIGHT CORROSION	DRY WEIGHT FOULING
2a	22	1	14	99
2b			35	79
11a	13	3/4	565	76
11b			530	64
12a	27	1	76	92
12b			21	64
17a	8	3/4	440	87
17b			718	123
21a	22	1	5	109
21b			25	95
30a	27	3/4	198	81
30b			165	77
33a	28	1/2	206	89
33b			270	98
43a	24	1	376	92
43b			118	146
45a	9	3/4	161	45
45b			568	197
52 (a & b averaged)	28	1	138	129
53 (a & b averaged)	17	3/4	99	79
61a	17	3/4	354	90
61b			374	97

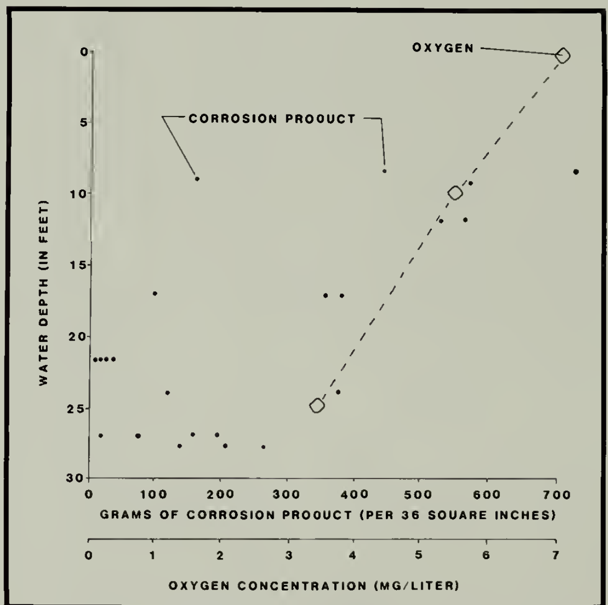


Figure 4.6. *Plot of water depth versus grams of corrosion product removed from 36-inch square areas of steel surface at vertical photostations on the USS ARIZONA. For comparative purposes, typical oxygen concentrations that occur at surface and two midwater depths (R.S. Henderson, unpublished Pearl Harbor survey data, 1978-1986) are provided.*

biofouling. Hard fouling at all stations was found to consist of entwined masses of oyster and vermetid shells. Hard fouling extended beneath the bottom silt on hull surfaces, and was exposed by digging holes about 3 feet into the silt at representative locations; that hard fouling layer had apparently grown on the lower hull areas before they were covered with silt by sedimentation or hull settling.

No correlation was found to exist between water depth and thickness of hard fouling, indicating that, over the long term, growth of oysters and vermetids had been relatively unaffected by depth and water motion. Hard fouling averaged about 3/4-inch thickness on vertical stations, where that layer serves as a primary barrier in protecting underlying steel/oxides from corrosive effects of overlying water and, at present, appears to be stable and well-bonded to the hull.

Dry weights of fouling growth scraped from 36-inch-square areas at the photo biostations ranged from 45 to 197 grams (Table 4.3). No correlation exists between fouling dry weight (or hard fouling thickness) and the amount of dry-weight corrosion product underlying that fouling. However, a plot of grams of corrosion product per scraping area versus water depth (Figure 4.2) indicates that formation of corrosion products has been maximal at shallower depths and has occurred at lower rates at depths of 20 to 30 feet. This correlation is consistent with the fact that oxygen, which accelerates corrosion by serving as a cathodic depolarizer, also declines with depth in Pearl Harbor waters.

No traces of coral growth were found on or mixed in any of the hard fouling examined on the hull or superstructure surfaces. Lack of any coral growth on the USS ARIZONA hull, which had been submerged for nearly 45 years at time of study, agrees with observations that live hard corals have apparently not existed in Pearl Harbor in historic times.

Data regarding the presence/absence of biofouling and the rate of coverage was obtained by examination of the biostation photographs combined (averaged) with in-situ visual data, presented here in Table 4.2. The photo slides are in the possession of NPS (Arizona Memorial) for comparison with photos of the same biostation areas that may be obtained in future monitoring studies.

Biofouling now present on the USS ARIZONA consists largely of filter-feeding organisms that depend primarily on plankton and suspended detritus for food. The high concentrations of those food items found in Pearl Harbor are in turn dependent on abundant supplies of dissolved nutrients (primarily nitrogen and phosphorus compounds) derived from freshwater influx (streams and springs) and domestic sewage. As nearly all sewage discharge has been terminated in recent years, it is expected that plankton populations will decline drastically in abundance as residual nutrients are slowly discharged from the harbor.

Because it is not known how long "excess" nutrients will be recycled or stored in the harbor, it is difficult to assess potential time frames and degrees of effects that sewage diversion will have on Pearl Harbor fouling communities. Additionally, data relating to the biological condition of Pearl Harbor prior to accumulation of sewage (nutrient) pollutants is very sparse and of no predictive value.

It should be noted that even if it were known with certainty that fouling communities would be reduced significantly by declines in pollution, that there are probably no practical ameliorative measures that could halt those declines. A recommended strategy is to establish a long-term program to monitor fouling growth on the hull. Annual inventory of density and composition of fouling at the photo biostations (which are marked by attachment studs) would probably be sufficient to define changes in the biofouling layer that would be of possible consequence to corrosion potential of the hull.

Sedimentation and Condition of Horizontal Surfaces

Methods

Fifty-five locations on horizontal surfaces of the ship were marked for examination of sediment type and depth (Figure 4.7). Because most of the ship's superstructure had been removed in the salvage operations, most of the study stations had to be situated over main deck surfaces, primarily of teak wood. Station depths ranged from 5 to 18 feet.

Horizontal stations were marked with two half-inch squares of 1/8-inch plexiglass on which station numbers had been engraved using a hot soldering iron tip. Each plexiglass number tag was glued onto the top of a 6-inch-long piece of 1-inch-diameter PVC pipe, and the opposite end of the pipe was secured to the flat side of a square 3-pound lead diver's weight with a plastic electrical tie. The number tags were painted with antifouling paint to ensure readability of the station numbers for two to three years. The markers were placed on sediment surfaces with tags facing upward. At some stations where sediments consisted of deep mud, 1-foot squares of plexiglass were placed under the lead weights to keep them from sinking into the mud.

After horizontal stations were marked, a pair of divers visited those stations and observed sediment character and underlying deck conditions. To determine sediment thickness, a 3-foot-long, 3/8-inch-diameter steel rod was pushed into the sediment until hard substrate was encountered. The size, spectrum and type of sediment particles present were noted, and observations were recorded on the type and abundance of biota present, such as mat-forming tube worms and sponges. Where sediment thicknesses were less than about 1 foot, holes were dug to expose small patches of underlying deck. Composition of the exposed deck areas was determined visually, and the corrosion or decomposition state of that material was noted. Holes were filled in when observations were completed.

Close-up photographs (color slides taken with 3:1 lens) were taken of typical sediment surfaces on horizontal surfaces. Copies of those slides are on file with NPS Arizona Memorial.

Results

Descriptions of sediment, biota and underlying surfaces observed at the horizontal stations are presented in Table 4.4. Four distinct zones of differing sediment types were delineated:

Zone 1

Aft area, about 40 percent of ship length (Stations 1 through 22). This area lies in an average depth of 8 to 10 feet. Sediment is generally 1 to 6 inches deep and is characteristically about 50 percent sand, 20 percent rubble, and 10 percent mud/silt. The sediment is held together in a spongy mat by pervading growth of colonial feather-duster worms (Branchiomma cingulata) and sponges. Large feather-duster worms (Sabellastarte sanctijosephi) inhabit the sediment in densities of about 1 to 5 per square meter. Encrusting and erect spon-

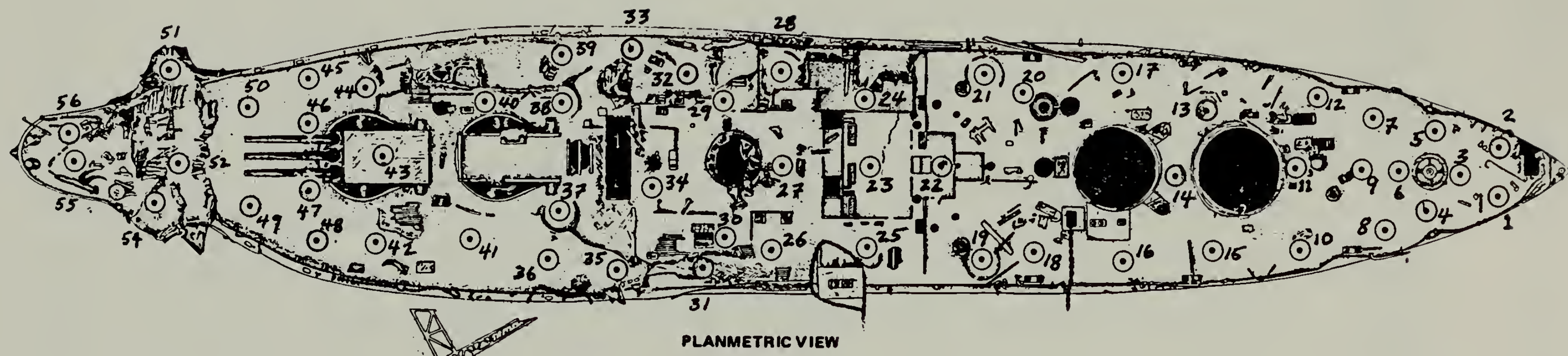


Figure 4.7. Locations of horizontal surface monitoring stations on the USS ARIZONA.

Table 4.4. Horizontal stations, USS ARIZONA, descriptions of sediment, biota and underlying surfaces.

Station 1
Sediment 1–2" deep. Sandy rubble held together in spongy mat by Branchiomma and sponges. Branchiomma very abundant and sponges in about 20% planar coverage. Sediment about 10% silt, 50% sand, 20% rubble and 20% Branchiomma tubes and burrowing sponges. About 3 sabellids (large feather duster worms) per sq. m.

Smooth teak under sediment.

Station 2
Sediment 3/4–1" deep. Sediment same as station 1.

Teak with burrow holes and some coverage of hard fouling.

Station 3
Sediment 2 1/2" deep. Sediment same as station 1.

Smooth teak under sediment.

Station 4
Sediment 4" deep. Sediment same as station 1.

Smooth teak under sediment.

Station 5
Sediment 2 1/2" deep. Sediment same as station 1.

Smooth teak under sediment.

Station 6
Sediment 3" deep. Sediment same as station 1.

Smooth teak under sediment.

Station 7
Sediment 3/4–1 1/2" deep. Sediment same as station 1.

Teak with some burrows under sediment.

Station 8
Sediment 4–5" deep. Sediment same as station 1.

Smooth teak under sediment.

Station 9
Sediment 4 1/2" deep. Sediment same as station 1.

Smooth teak under sediment.

Station 10
Sediment 4 1/2" deep. Sediment same as station 1.

Smooth teak under sediment.

Station 11
Sediment 4–12" deep. Sediment same as station 1.

Surface below sediment is irregular, corroded metal and hard fouling.

Station 12
Sediment 1 1/2–2 1/2" deep. Sediment same as station 1.

Smooth teak under sediment.

Station 13
Sediment 6" deep. Sediment same as station 1.

Smooth teak under sediment.

Station 14
Sediment 10–13" deep. Overlying sediments same as station 1, but at 3" depth sediment grades into coarse rubble (largely oyster shells and vermetid worm tubes) admixed with silt and sand.

Surface under sediment felt like wood, but could not see surface because of turbidity in hole.

Station 15
Sediment 5" deep. Sediment same as station 14.

Smooth teak under sediment.

Station 16
Sediment depth exceeded 18" probe length. Sediment as as station 14.

Surface beneath sediment in nearby area felt like wood from probe contact.

Station 17
Sediment 4" deep. Sediment same as station 14, but burrowing sponges more abundant.

Smooth teak under sediment.

Station 18
Sediment 5–7" deep. Sediment 60% silt/mud, 20% rubble, 10% sand and 10% sponges. Snapping shrimp burrows present.

Surface below sediment not observed.

Station 19
Sediment 9–10" deep. Sediment 75% rubble with sand and wilt admixed. Abundance of sponges in sediment. About 10% of sediment surface covered with erect "finger" and "ball" sponges. Branchiomma uncommon here.

Surface below sediment not observed.

Station 20

Sediment 7–8" deep. Sediment 40% Branchiomma, 20% sponges, 15% rubble, 10% and, and 15% silt/mud.

Teak under sediment. Condition not noted.

Station 21
Sediment 9" deep. 50% rubble, 20% sponges, 10% Branchiomma tubes, 10% sand, and 10% silt/mud.

Surface under sediment not observed.

Station 22
Sediment 3–6" deep. Sediment same as station 21.

Surface under sediment is corroded metal.

Station 23
Sediment 5" deep. Sediment 60% rubble (40% oyster shells, 20% vermetid tubes, some coins and porcelain fragments), 15% mud/silt, 15% sand, 5% sponges and 5% Branchiomma.

Surface under sediment is porcelain tile in good condition.

Station 24
Sediment 5–10" deep. Sediment 50% rubble, 25% silt/mud, and 25% sand. snapping shrimp and commensal goby fish present.

Surface under sediment not observed.

Station 25
Sediment 4–6" deep. Sediment 80% rubble with some very large (4–8" diameter) on surface. Some 50 caliber bullets seen on sediment surface. About 5 sabellids per meter square. Branchiomma rare. Some solitary tunicates on sediment surface.

Surface under sediment is corroded metal that is exfoliating in 2–4" flakes that are about 1/8" thick.

Station 26
Sediment 1-4" deep. Sediment 75% rubble, 10% mud and sand, 10% sponges, and 5% Branchiomma.

Unidentified hard surface under sediment is overlain by at least 1" of black, "crusty" tar-like substance.

Station 27
Sediment 3-4" deep. Sediment similar to station 23. Some surface and burrowing sponges (about 1-2% of sediment surface).

Surface under sediment is heavily corroded metal that is reddish brown and black in color and is overlain by the same tar-like substance described above.

Station 28
Sediment 2-3" deep. Sediment 70% rubble, 10% mud/silt, 5% sand, and 15% sponges.

Surface under sediment similar to station 27.

Station 29
Sediment 10" deep. Sediment 90% rubble with some sand and very little silt/mud in upper layers. Fines concentrated deeper in sediment. Five sabellids per square meter.

Surface under sediment is corroded metal.

Station 30
Sediment 4-7" deep. Sediment 70% rubble, 10% sand, 10% sponges, and 10% silt/mud.

Surface under sediment is grey steel overlain by tar-like substance.

Station 31
Sediment 1-9" deep. Sediment similar to station 30.

Surface under sediment is grey steel overlain by tar-like substance.

Station 32
Sediment 3-9" deep. Sediment similar to station 30.

Surface under sediment is grey steel.

Station 33
Sediment 8-16" deep. Sediment 50% rubble, 20% sponges, 20% Branchiomma, and 10% silt/mud/sand.

Surface under sediment not observed.

Station 34
Sediment 5-ll" deep. Sediment 70% rubble, 10% sponges, 10% Branchiomma, and 10% sand/silt/mud.

Surface under sediment not observed.

Station 35
Sediment 3-20" deep. Sediment 50% rubble, 30% Branchiomma, 10% sponges, and 10% sand/silt/mud.

Surface under sediment is grey steel.

Station 36
Sediment 11-18" deep. Sediment similar to station 35.

Surface under sediment not observed.

Station 37
Sediment 21-24" deep. Sediment 50% rubble, 20% sponges, 10% Branchiomma, and 10% sand/mud.

Surface under sediment not observed.

Station 38
Sediment 9-15" deep. Sediment 60% rubble, 15% sand, 10% silt, and 15% sponges. No Branchiomma were noted there.

Surface under sediment not observed.

Station 39
Sediment 17-37" deep. Sediment 95% mud/silt and 5% sand.

Surface under sediment not observed.

Station 40
Sediment 12-17" deep. Sediment 50% Branchiomma, 25% mud/sand, 15% sponges, and 10% rubble.

Surface under sediment not observed.

Station 41
Sediment 24" to over 36" deep. Sediment 60% rubble, 10% Branchiomma, 20% sponges, 10% sand/silt/mud.

Surface under sediment not observed.

Station 42
Sediment 7-11" deep. Sediment 80% silt/mud, 15% rubble, and 5% sand.

Surface under sediment not observed.

Station 43
Sediment 1-2" deep. Sediment 70% Branchiomma, 10% sponges, 10% sand, and 10% mud/silt.

Surface under sediment is steel (armor plate) covered with a thin blackish finish.

Station 44
Sediment more than 36" deep. Sediment 90% silt/mud and 10% sand.

Surface under sediment not observed.

Station 45
Sediment more than 36" deep. Sediment 90% silt/mud, 5% rubble, and 5% sand.

Surface under sediment not observed.

Station 46
Sediment more than 36" deep. Sediment same as station 45.

Surface under sediment not observed.

Station 47
Sediment more than 36" deep. Sediment same as station 45.

Surface under sediment not observed.

Station 48
Sediment 39" deep. Sediment same as station 45.

Surface under sediment not observed.

Station 49
Sediment 24" deep. Sediment same as station 45.

Surface under sediment not observed.

Station 50
Sediment 20" deep. Sediment same as station 45.

Surface under sediment not observed.

Station 51
Sediment 8-14" deep. Sediment 40% Branchiomma, 20% mud/sand, 30% rubble, and 10% sponges.

Table 4.4. (concluded)

Surface under sediment not observed.

Station 52
Sediment 12–17" deep. Sediment 40% Branchiomma, 20% mud/sand, 25% rubble, 15% sponges.

Surface under sediment not observed.

Station 53 – No station

Station 54
Sediment 1" deep. Sediment 95% rubble and 5% silt/mud.

Corroded metal under sediment. Bathycorrometer reading = 0.572.

Station 55
Sediment 4" deep. Sediment same as station 54.

Wood (teak?) under sediment.

Station 56
Sediment 8" deep. Sediment same as station 54.

Corroded metal under sediment.

Figure 4.7A Area is cleared on deck for installation of horizontal surface monitoring stations. (NPS photo by Larry Murphy)

Figure 4.7B Horizontal surface monitoring station marker in place. (NPS photo by Larry Murphy)

ges are common on the sediment surface in area coverage of 1 to 10 percent.

Most substrate underlying Zone 1 sediment is teak wood. Teak is smooth and relatively dense under the thickest sediment layer. Finger-sized burrows, largely created by burrowing mollusks (primarily Martesia striata and possible Teredinid species), are evident in teak that is exposed or covered by thinner sediment cap. The color of teak in some areas is normal, whereas in other areas it has been blackened, possibly stained by exposure to sulfide compounds formed in anoxic environments under thicker sediment.

Gelatinous veneers of fish eggs (clear to purplish in color) are commonly found laid on teak and smooth metal areas that are exposed in Zone 1. Egg nests are often situated in areas that appear to have been naturally exposed by water motion, but more than 50 percent of the nest depressions have apparently been created or enhanced by fanning actions of egg-laying fish. These egg nests are likely built by the Maomao (Sargeant Major fish, Abudefduf abdominalis) that schools abundantly on the wreck. An estimated 100+ nests of 1-to-3-foot diameter were present in Zone 1 at the time of the survey.

Teak surfaces exposed in fish-egg nests exhibit considerably more mollusk-burrow damage than surfaces covered by sediment. Therefore, nesting activity should be considered as a potential chronic, deleterious process that should be monitored in future studies. Such monitoring should examine the density and seasonality of nesting activity and should compare the decomposition state of wood areas in and near nests to the control sites continuously covered by moderate sediment thickness.

Metal surfaces were encountered under sediment at only two stations in Zone 1, and that material was largely irregular texture corrosion products.

Zone 2

Midships, about 25 percent of ship length (Stations 23 through 38). Depths in this area range from about 4 to 10 feet. Sediments are characterized by high rubble content (50 to 90 percent) with lesser quantities of sand and mud/silt. Coins were very common in the sediment immediately beneath the visitor viewing area of the Arizona Memorial.

Colonial tube worms and burrowing sponges are present, although in much lesser abundance than in the finer sediments of Zone 1. Erect and encrusting sponges are present at some stations. Alpheid snapping shrimps and commensal gobies are common in burrow complexes in the sediment.

The higher content of coarse material in these sediments is probably due to the presence of superstructure that provides abundant vertical substrate conducive to growth of vermetid worms and oysters. Those organisms provide shell material that comprises the bulk of the rubble. Also, the surge tends to wash finer sediments out of this shallow zone or works them into concentrated horizons in lower sediment layers.

The occurrence and thickness of mud/silt horizons under the rubble varied considerably from station to station, and where present often made viewing of the underlying ship fabric difficult or impractical because of persistent turbidity. Surfaces encountered under sediment were usually irregular corroded metal of reddish-brown or blackish coloration.

In several areas a black "tarry" hydrocarbon layer 3/4 to 2 inches thick existed over grey metal. The tarry layer is probably made up of heavier fractions of fuel oil that has settled into the lower sediment horizons over the 45-year interval since the ship's sinking. That layer appears to provide some corrosion protection to the deck steel, because most oxides observed under the layer were darker (black and grey) forms resembling "stable" oxides (magnetite and hematite). Deck surface under sediment at Station 23 was found to be porcelain tile in good condition. That area is reported to have been the ship's galley.

Zone 3

Area surrounding gun turrets No. 1 and 2, and about 25 percent of ship length (stations 39 through 50). Depths in this area are about 20 to 25 feet. Sediments are predominantly (75 to 95 percent) mud and silts with some admixed rubble and sand. These fine sediments are generally 2 to 3 + feet in thickness and contain abundant burrows of alpheid snapping shrimp and portunid crabs. Colonial feather-duster worms and sponges occur on the sediment surface in some areas but are generally rare.

Water motion in this zone is gentle and turbidity is high, indicative of an area of high sedimentation. Some of the turbidity and influx of suspended fine sediment to this area is probably caused by propeller wash from shuttle boats going to and from the Arizona Memorial dock.

Fabric underneath a 1- to 2-inch layer of "Branchiomma mat" on the top of gun No. 1 was found to be shiny steel armor plate covered by a thin black oxide coat. Surfaces under sediments at all other stations in this zone were not examined because of the extreme thickness of sediment and the turbid conditions.

Zone 4

Bow deck, 12 percent of ship length (Stations 51 through 56). Depths range from 4 to 10 feet. Sediments in this zone are similar to those found in Zones 1 and 2 (as described above) and ranged from 1 to 17 inches in thickness. Fabric under one station was found to be wood (probably teak), and corroded metal was observed under sediment at the other two stations where examination holes were dug. Water motion conditions are similar to Zone 2.

Corrosion and Steel Fabric Thickness Study

Methods

Twelve stations were selected on hull and superstructure surfaces that had access to metal edges (Figure 4.4). At each station, divers used a claw hammer to chip away a few square inches of fouling growth and corrosion from both sides of the metal edge to expose shiny metal. Observations were then made of the thicknesses of dense fouling, black and grey oxides, and shiny steel that were visible in the exposed end sections.

These measurements were made in order to permit future corrosion engineers to estimate corrosion rates at those locations. Metal thicknesses of the steel fabric at the specific locations will have to be obtained from drawings/specifications of the ship that show its condition immediately prior to 1945. Those thicknesses can then be compared to the thicknesses obtained in later observations to estimate the amount of steel loss that has occurred.

It is recognized that surfaces on or near exposed edges might be affected by edge events that could alter measurements of corrosion, in other words, yielding higher corrosion rates than would occur on large-area flat surfaces. However, since sampling removal of metal pieces from flat areas was not allowed, it was decided to examine the edge corrosion to allow at least a worst-case estimation of corrosion rates.

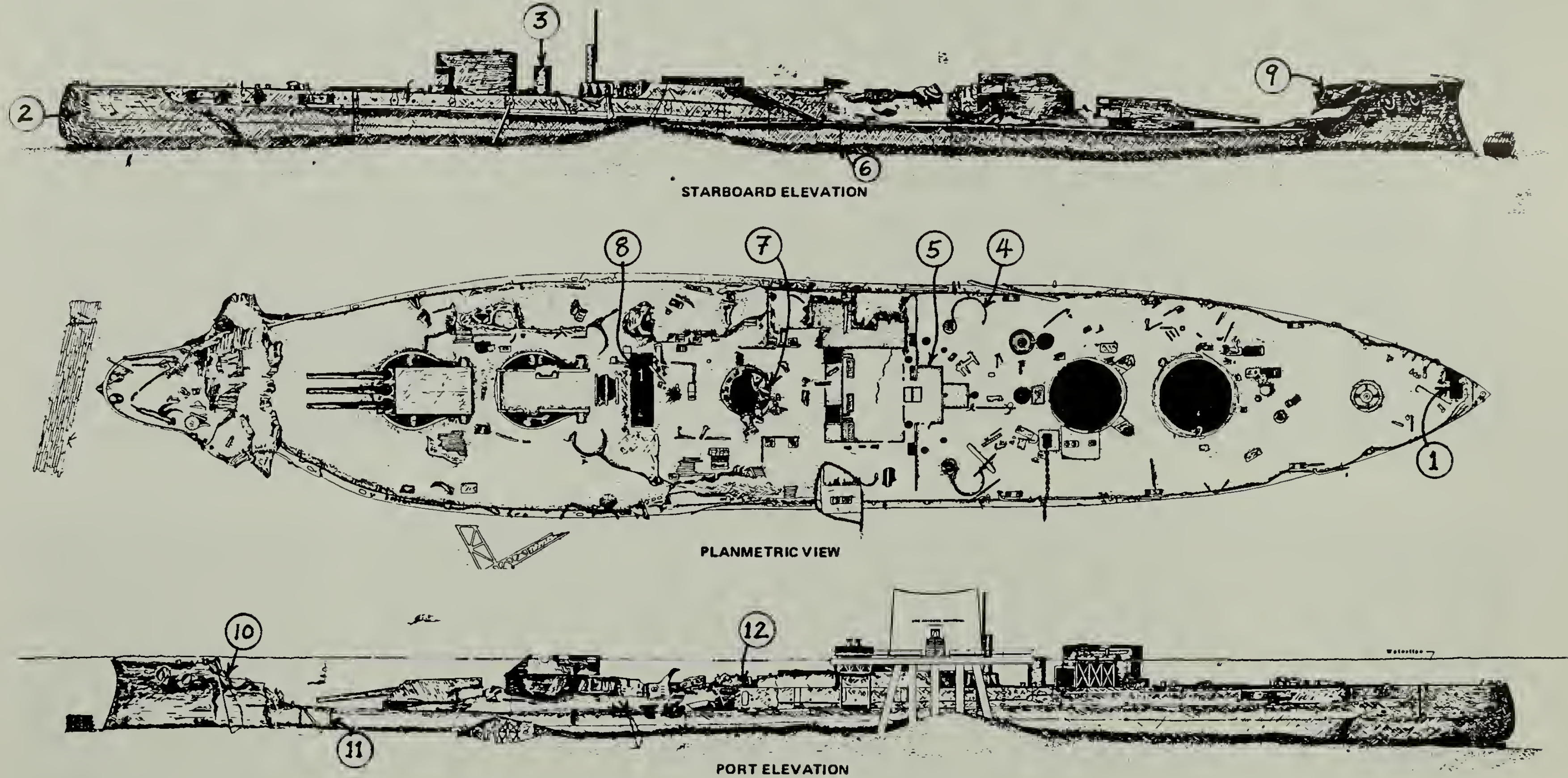


Figure 4.8. *Locations where measurements were made of thickness of corrosion products and underlying shiny steel on edge sections of hull and superstructure fabric on the USS ARIZONA.*

Table 4.5. Thickness (in millimeters) of hard fouling, black and grey oxide layers, and shiny steel of hull and superstructure edge sections on USS ARIZONA. Station locations are provided in Figure 4.8.

STATION	FOULING LAYER	BLACK LAYER	GREY LAYER	STEEL LAYER
1	35	15	12	13
2	20	8	0	2
3	15	5	1	2
4	20	12	1	10
5	20	1	0.5	1
6	35	10	7	5
7	20	6	3	5
8	15	7	2	0
9	30	5	3	3-1mm steel layers alternating w/2-3mm grey layers
10	30	6	5	5
11	25	12	3	10
12	30	5	3	15

Results

Data from observations of the edge sections are presented in Table 4.4.

Water Quality and Biofouling in Interior Spaces

Methods

Examination of biofouling and sediment coverage of walls and floors was done in some interior spaces where the presence of open portholes enabled observation. Divers simply inserted a flashlight at arm's length through portholes and visually scanned surfaces. Visibility was usually restricted to about 15 feet by the low intensity of the light used and by the small viewing openings provided by the portholes, which commonly had nearly 50 percent of their open area occluded by hard fouling.

Water motion and the flushing rate in interior spaces of the ship's hull are probably low, due to the scarcity of large openings connecting those spaces with ambient harbor water. It was also assumed that "stagnant" water trapped in interior spaces would exhibit oxygen and pH levels considerably lower than typical harbor water, primarily due to the effects of oxygen consumption by microbes and heterotrophic organisms. Under conditions of lowered oxygen, pH and water motion/flushing, it would be expected that abundance of fouling communities would diminish because of reduced availability of oxygen and water-borne food. On the other hand, corrosion rate of steel would be lessened by those very conditions of low oxygen and low water motion, but would be accelerated by the presence of low pH and sparse fouling coverage (ref. 2).

To assist in defining the chemical and biological conditions inside the ship, water quality was measured in water pumped directly from selected interior spaces. The pumping apparatus consisted of a 15-foot-long piece of 3/4-inch-diameter PVC pipe connected by 30 feet of 1-inch-diameter vinyl hose to a 12-volt water pump that was situated in a small boat. From the pump, water was delivered to a wet-well manifold on the boat that contained sensor probes for oxygen, pH and temperature measurements. A technician on the boat recorded data from the instruments (Yellow Springs Instruments Co. model 57 dissolved oxygen and temperature meter, and Beckman Co. model 1009 pH meter) when appropriate signals were received from the divers below.

Water-quality measurements were accomplished in six interior spaces (Figure 4.5). In the course of a typical measurement run, divers first held the pipe/hose intake about 2 feet away from the opening that accessed the space to be sampled. After the outside (ambient) water data had been recorded, the divers inserted the pipe into the opening to the full length of the pipe (15 feet) or until an obstruction was encountered. Water-quality measurements were taken at maximum insertion and, in three cases, also at 8 to 9 feet of insertion. After withdrawal of the pipe, a second set of ambient measurements were taken.

When water was being pumped at maximum pipe insertions, water samples were collected from the topside manifold port. Those samples were chilled and checked at the end of the sampling run for odors indicative of hydrocarbons or sulfides. Also, notes were made on the presence of visible sediment and hydrocarbons that appear in the pumped water.

Results

Fouling growth observed on interior surfaces through portholes and other openings was composed largely of vermetid worms and oysters occurring in patchy distribution. Although large clumps of fouling were often common within a radius of a few feet inside hull and superstructure openings, fouling coverage was generally less than 50 percent on interior walls and ceilings. Fine sediment covered most wall areas not covered by fouling, and silt/mud layers estimated at several inches to several feet in thickness covered all upward-facing horizontal surfaces. Ceiling areas contained patchy fouling. Unfouled surfaces were often black and flossy in appearance, probably being coated by hydrocarbon (fuel and oil) residues.

It was not possible to visually determine the corrosion state of interior surfaces because of coverage of fouling, sediment and hydrocarbons. However, exfoliating corrosion layers were not observed on any surfaces in the spaces deeper than about 8 feet, suggesting that high rates of corrosion were not occurring in those areas.

As expected, oxygen levels measured 15 to 16 feet inside interior spaces were substantially lower than ambient values (Table 4.5). At distances of 8 to 9 feet inside openings, oxygen levels were only moderately lower than ambient, indicating that water volumes within about 10 feet of hull openings are relatively well flushed. Oxygen concentrations were at or less than 1 mg/l at 15-foot distance from opening in 3 out of 6 stations, thus it would be reasonable to assume that most other enclosed volumes in the hull that are distant from openings would also exhibit sub-1 mg/l oxygen concentrations.

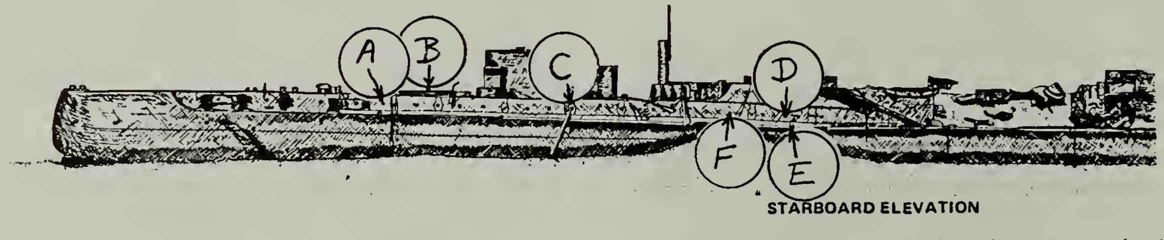


Figure 4.9. Locations of points of entry for water -quality measurements made in interior spaces in the USS ARIZONA.

Figure 4.10. *Water is drawn from interior spaces of the USS ARIZONA to surface through a PVC pipe and vinyl tube. Pipe is marked to establish exact distance of penetration. (NPS Photo by Larry Murphy)*

Figure 4.11. *On the surface, water drawn from inside the wreck was analyzed for oxygen, temperature and pH levels. (NPS photo by Larry Murphy)*

Temperature and pH values measured in interior spaces were only slightly below ambient values. Those differences were not large enough to alter the corrosion or biofouling status of interior metal surfaces.

At the three midships stations (D, E and F), viscous black hydrocarbon residue was encountered while pumping at maximum probe insertions. Water samples collected at those times had a distinct volatile hydrocarbon fuel odor. Hydrocarbons were pumped in pulses when the intake end of the probe pipe was allowed to drop down and thus sample water closer to or at the bottom level of spaces. These heavy-fraction hydrocarbons are thus trapped in low stagnant areas of the ship and will likely persist in those areas for a long time.

Low oxygen and near-normal seawater pH values documented in the spaces sampled would be expected to reduce corrosion rates substantially below those that would exist in high-oxygen harbor water (ref. 2). The presence of viscous hydrocarbon compounds as coatings on steel surfaces would further reduce availability of oxygen. Furthermore, oxygen consumption by microbes digesting hydrocarbon products would be another process that may help maintain an oxygen-depleted environment in the ship's stagnant areas. Collectively, these anticorrosion factors would probably more than compensate for the scarcity of protective biofouling cover expected on interior substrates.

Bathycorrometer Measurements

A description of te methods used to obtainbathycorrometer measurements and a listing of the resultant measurements are provided in Table 4. 7 of this report. A copy of the data has been given to metallurgical engineers at Pearl Harbor Naval Shipyard for analysis.

Results: Summary and Recommendations

1. Biofouling has created a uniform layer of stable hard fouling that covers most of the hull and superstructure remnants of USS ARIZONA. That layer maintains anoxic conditions near the exterior steel surfaces and encourages formation of stable black and grey iron oxides. Corrosion products on hull showed a moderate trend toward decreasing thickness as water depth increased.

2. Most rapid corrosion has occurred on superstructure surfaces located about 6 feet above and below sea level. In this high-oxygen and high-water motion zone, corrosion has caused extensive deterioration and exfoliation of steel surfaces.

3. Application of protective coatings (such as epoxy paints) to surfaces in the high-corrosion zone would probably not be practical because of their advanced state of deterioration. Proper prepainting preparation of such surfaces would entail removal of oxide products to a degree that would likely cause further structural weakening.

4. Corrosion damage did not appear significant in the few interior spaces examined. Water-quality environment and presence of hydrocarbons should maintain reduced rates of corrosion in interior volumes as long as water flushing in those spaces remains low.

5. Potential exists for a decline in abundance of live biofouling on the ship due to a projected long-term decline of nutrients (food) available for filter-feeders. It is recommended that biofouling be monitored at the permanent photo-stations (established in this survey) on an

Table 4.6. Oxygen, pH and temperature measurements made inside hull openings shown in Figure 4.9. Units: 02 = mg/liter (ppm), pH = pH units, temperature = degrees centigrade.

LOCATION A -- Porthole about 3 feet below starboard gunnel. About even with aft end of No. 4 gun foundation. Depth = about 10 feet.

Water Source	02	pH	temp
Ambient (Outside porthole)	5.2	8.1	27.0
9 feet inside porthole	4.2	8.05	26.5
15.5 feet inside porthole	3.8	8.0	26.5

LOCATION B -- 25-foot depth inside No. 4 gun foundation "well."

Water Source	02	pH	temp
25 foot depth	3.25	8.05	26.5

LOCATION C -- Porthole about 3 feet below starboard gunnel. About even with forward end of No. 3 gun foundation. Depth = about 10 feet.

Water Source	02	pH	temp
Ambient (Outside porthole)	5.1	8.1	26.8
16 feet inside porthole	1.0	8.05	26.5
8 feet inside porthole	4.0	8.1	26.5
Ambient (Outside porthole)	5.3	8.1	27.0

LOCATION D -- Porthole about 3 feet above starboard gunnel. About 5 feet aft of bio/photo station No. VS18. Depth = about 10 feet.

Water Source	02	pH	temp
Ambient (Outside porthole)	5.3	8.1	26.8
8 feet inside porthole	3.7	8.1	26.5
15 feet inside porthole	0.6	8.05	26.0
Ambient (Outside porthole)	5.2	8.1	26.7

LOCATION E -- Open inspection hatch on main deck near starboard gunnel. Below location D. Depth = about 13 feet. Opening extends downward on vertical axis.

Water Source	02	pH	temp
Ambient (Outside hatch)	5.2	8.15	26.6
14 feet down hatch	0.5	8.3	25.4
Ambient (Outside hatch)	5.2	8.15	26.6

LOCATION F -- Fourth porthole aft of location D on starboard side. Immediately below Arizona Memorial structure. Depth = about 10 feet.

Water Source	02	pH	temp
Ambient (Outside porthole)	5.0	8.15	26.7
12 feet inside porthole	2.9	8.05	26.5
Ambient (outside porthole)	5.2	8.15	26.7

Table 4-7 Bathycorrometer measurements - USS ARIZONA

Method used for bathycorrometer measurements: Prior to dive ops, instrument was turned on and suspended in seawater for about 30 minutes for equilibration. Soft and hard fouling growth was scraped away from metal surfaces (about a 2-inch diameter area) and black and grey oxide coatings over shiny metal were penetrated. Preliminary measurements had shown that readings made on black and grey oxides (presumably composed primarily of magnetite and hematite, respectively) were not consistently the same as readings made on shiny steel - thus all subsequent readings were made only on clean steel.

Measurements on the USS ARIZONA were made on: 1. vertical exterior hull surfaces, 2. superstructure surfaces, 3. a few hull surfaces beneath silt line, and 4. at and just below water surface at a few superstructure sites. Additionally, a few measurements were obtained from gunnel and superstructure locations on the USS UTAH in the course of one dive.

Control/drift check measurements were usually made on a gunnel site on the USS ARIZONA that was located about midship on port side. Drift was generally in the range of 0.002 volt over the course of a 1 to 2 hour dive.

Other notes: Fouling thickness measurements (in centimeters) include is total thickness of live and dead fouling. Dead fouling on most vertical surfaces averaged 1 to 2 cm thickness. Most of that material consisted of oyster and vermetid mollusk worm tubes that adhered tightly to the underlying oxide surfaces. Exfoliated = irregular oxide/steel plates delaminating from hull. Some exfoliated areas may actually be areas where a double hull exists with gaps of 1 to 5cm between plates. Areas of active corrosion, exfoliation and "delamination" were actually rare on the hull and superstructure surfaces deeper than 5 feet below surface.

VERTICAL STATIONS DATA

Note: Readings were made in closer area spacing on the forward port side of the USS ARIZONA. When it became evident that there was very little variation in readings, measurements were made only at tagged biological observations (numerical designation) stations.

STA	FOULING (cm)	BLACK LAYER (mm)	VOLTS	NOTES
Contr	2 - 5	3 - 5	.587	16 Jul 85
60	2 - 8	5 - 10	.579	
61	2 - 6	5 - 10	.583	
A	5 - 15	10 - 15	.585	
B	1.5 - 5	10	.580	

Table 4.7. (continued)

STA	FOULING (cm)	BLACK LAYER (mm)	VOLTS	NOTES
C	1 - 8	10 - 15	.581	
D	1 - 7	15	.582	
57	1 - 4	15	.583	
58	1 - 6	15 - 30	.583	
59	1 - 8	15 - 20	.584	
E	1 - 3	5	.587	
F	2 - 13	15 - 25	.586	.592-17 Jul reading same site
56	2 - 10		.591	
G	1 - 5	10 - 20	.594	exfoliated - hvy yellow
55	1 - 3	10 - 15	.601	
54	1 - 4	5 - 10	.578	
53	1 - 4	<5	.575	
H			.576	
Contr			.587	stop 16 Jul 86
Contr	3 - 8	25 - 30	.589	start 17 Jul 86
I	1 - 5	1 - 10	.579	
J	1 - 5	1 - 15	.584	exfoliating
K	5 - 15	10 - 20	.583	
L	2 - 6	1 - 10	.593	
M	5 - 10	2 - 10	.592	
O	1 - 3	5 - 15	.592	exfoliating
P	1 - 4	15 - 25	.569	
Q	1 - 2	5 - 10	.574	
R	1 - 2	15 - 20	.562	
S	1 - 4	20 - 30	.571	
T	3 - 5	20 - 30	.597	exfoliating
U	2 - 5	20 - 3	.596	exfoliating
52	1 - 7	25 - 40	.592	
51			.584	exfoliating
Contr			.589	
Contr	2 - 5	10 - 25	.588	
V	2 - 6	25 - 35	.587	
W	2 - 6	<5	.591	
X	2 - 6	15 - 25	.592	
Y	1 - 4	5 - 15	.591	gas
Z	2 - 4	10 - 15	.590	
AA	2 - 4	<5	.591	gas
AB	2 - 5	10 - 15	.589	
50	5 - 7	10 - 30	.591	
49	1 - 2	15	.592	exfoliating
48	1 - 4	10	.587	
47	1 - 4	10	.591	
46	2 - 6	10	.596	
45	2 - 6	5	.590	

Table 4.7. (continued)

STA	FOULING (cm)	BLACK LAYER (mm)	VOLTS	NOTES
44	2 - 6	5 - 10	.592	
43	2 - 6	5 - 10	.591	
42	2 - 6	5 - 15	.588	exfoliating
41	2 - 6	10 - 15	.591	
40	1 - 3	5 - 15	.594	
39	2 - 5	15 - 20	.585	exfoliating
38	1 - 4	10	.587	exfoliating
37	1 - 3	5 - 15	.583	
36	5 - 10	5 - 15	.580	
35	5 - 10	5 - 10	.571	
34	2 - 8	10 - 20	.573	
33	2 - 8	5 - 10	.578	
32	2 - 4	<5	.586	exfoliating
31	2 - 3	<5	.574	
30	2 - 4	10 - 15	.581	
29			.591	
Contr			.588	stop 17 Jul 86
Contr	1 - 3	5 - 10	.593	start 18 Jul 86
28	1 - 3	5 - 10	.586	
27	1	<5	.593	
26	1 - 4	10	.600	exposed scar
25	1 - 3	<5	.595	
24	1 - 5	5 - 15	.595	
23	1 - 5	5 - 10	.597	
22	1 - 3	5 - 10	.596	
21	1 - 5	5 - 10	.598	
22	1 - 3	5 - 10	.596	
21	1 - 5	5 - 10	.598	
20	1 - 6	<5	.602	exfoliated w/1cm gap
19	1 - 5	5 - 15	.595	
18	1 - 4	10	.597	
17	3	5 - 10	.593	exfoliating
16	1 - 3	<5	.592	
15	1 - 3	<5	.592	exfoliating
14	1 - 3	<5	.588	
13	1 - 4	5 - 10	.596	
12	3	5	.605	
11	3 - 6	5 - 10	.592	exfoliated w/1cm gap
10	1 - 3	<5	.575	
9	3 - 6	5	.581	
8	2 - 6	5 - 10	.587	
7	10	<5	.588	
6	2 - 5	5 - 10	.579	
5	2 - 5	5 - 10	.583	exfoliated

Table 4.7. (continued)

STA	FOULING (cm)	BLACK LAYER (mm)	VOLTS	NOTES
4	2 - 4	<5	.588	exfoliated
3	1 - 3	<5	.586	.290 on grey layer
2	2 - 4	<5	.588	
1			.587	exfoliated
50			.594	
49			.598	
48			.590	.587 previously

SUPERSTRUCTURE STATIONS DATA

STA	FOULING (cm)	BLACK LAYER (mm)	VOLTS	NOTES
Contr			.590	21 Jul 86
1	1	<2	.568	#2 gun ear
2	1 - 3	5 - 10	.568	#2 gun turret
3	2 - 6	10 (black/grey)	.579	nterior #2 gun turret
4	2 - 7	10	.578	interior #2 gun turret
5	1 - 4	10	.569	#2 gun turret
6	1 - 4	<2	.567	#2 gun ear
7	1 - 2	2	.586	interior wall
8	1 - 6	5 - 10	.586	interior wall
9	2 - 4	<2	.561	interior wall stack base
9	1 - 4	2/3 (black/grey)	.563	exterior wall stack base
10	1 - 5	10 - 20	.580	ext wall stbd gun tub
11	1 - 3	3 - 5	.574	stbd #3 gun foundation
12	1 - 4	<5	.579	exterior wall #4 gun found
12	1 - 2	<5	.576	exterior wall #4 gun found
13	1 - 2	<5	.583	aft ext wall stbd stairwell
14	1	<3	.580	aft ext wall port stairwell
15	0.5	<1	.585	center launch crane base
16	-	-	.641	stern anchor scraping
17	0.1	10 - 20	.583	ext wall stern vent
18	1	4/4 (black/grey)	.580	ext wall forw stern vent
19	1 - 2	<4	.576	ext port #4 gun foundation
19	1 - 4	10	.576	int port #4 gun founcation
20	1 - 2	5 - 8	.574	port #3 gun foundation
			.616	aft dock chain (recent?)
21	1 - 3	?	.581	vent forward of #2 gun foun
22	1 - 6	3/10 (black/grey)	.585	port ext wall gun tub
Contr			.589	21 Jul 86

Table 4.7. (continued)

SUBSILT HULL DATA

Note: Holes were dug into silt adjacent to hull at four locations on both port and starboard sides. Holes were about 2.5 feet deep and hull at all subsilt locations was found to be covered with layer of dead, hard fouling. Depth of bathycorrometer reading (below silt surface) is given in notes column.

STA	FOULING (cm)	BLACK LAYER (mm)	VOLTS	NOTES
Contr			.599	22 Jul 86
62	1 - 4	<5	.595	Below sta VP1 - d = 1.5 ft
52	1 - 3	<5	.602	Below sta VP4 - d = 2 ft
44	1 - 3	<5	.599	Below sta VP7 - d = 2 ft
33	1 - 3	<5	.583	Below sta VP10 - d = 2 ft
Contr			.593	22 Jul 86
Contr			.592	23 Jul 86
3	1 - 2	5 - 10	.590	Below sta VS1 - d = 1.5 ft
VS6	1 - 2	<5	.599	Below sta VS6 - d = 1.5 ft
Contr			.592	23 Jul 86
Contr			.592	23 Jul 86
7	1 - 2	<5	.602	Below sta VS7 - d = 2 ft
VS10	1 - 3	<5	.585	Below sta VS10 - d = 2 ft
VS3	1 - 3	<5	.593	Below sta VS3 - d = 2 ft
Contr			.592	23 Jul 86

NEAR-SURFACE TRANSECT DATA

These measurements were perfomed on superstructure pieces that penetrated the water surface. B = water line, C = 1.5 foot below water line, D = 3 feet below water line.

STA	FOULING (cm)	BLACK LAYER (mm)	VOLTS
1B	1 - 3	<5	.574
1C	1 - 3	<5	.578
1D	1 - 3	<5	.578
2B	1 - 4	<5	.578
2C	1 - 3	5 - 10	.582
2D	1 - 3	5 - 10	.582
3B	1 - 6	<5	.576
3C	1 - 5	20 - 25	.580
3D	1 - 4	15 - 20	.579

Table 4.7. (continued)

STA	FOULING (cm)	BLACK LAYER (mm)	VOLTS
4B	1 - 5	<5	.572
4C	1 - 5	5 - 10	.576
4D	1 - 5	5 - 10	.574
5B	1 - 4	5 - 10	.580
5C	1 - 5	10 - 15	.581
5D	1 - 6	5 - 10	.579
VS48			.607
VS49			.616
VS11			.629
6B	1 - 6	10 - 15	.585
6C	2 - 10	5 - 15	.586
6D	1 - 4	5 - 10	.586
7B	1 - 5	5 - 10	.582
7C	1 - 3	3 - 6	.582
7D	1 - 4	5 - 10	.584
8B	1 - 6	5 - 15	.585
8C	1 - 4	5 - 10	.584
8D	1 - 4	5 - 10	.584

MISCELLANEOUS BATHYCORROMETER READINGS FROM USS UTAH

25 July 1986 - R. Scott Henderson

VOLTS	NOTES
.965	On galvanized dive ladder in water.
.598	On gunnel at bow.
.597	On anchor chain hole in hull - port gunnel.
.599	On vertical closed cylinder about 3 feet in diameter with cross-section like a keyhole. 1/2" black layer over steel 1/2" fouling.
.591	Pipe-like structure with "crowsnest" on top - lying on deck, 5 feet north of BP20.
.588	On jumbled steel beams and plate - corrosion/fouling as per previous station.
.588	On block-like structure at CP60 that measures about 3'X3'X5' - very thin fouling over what appears to be bronze or brass.

Table 4.7. (concluded)

VOLTS	NOTES
.582	Large superstructure surface - @E5 clip - black layer with some white laminations inside.
.578	Objects on wood deck that look like "nuts" measuring about 8"X8"X3" high made of brass or bronze.
.585	Round stack near clip P3.
.596	Large diameter salvage cable about 15' NE of FS20.
.588	Steel nearly exposed on hull by fish nest about 15' SW of FS20.
.590	Gunnel at 6.
.593	Bollard top at clip V7.
.290	Reading in normal salinity seawater at about 5' depth.
.280	Reading in lower salinity seawater near surface. No contact with solid substrates on these two readings.

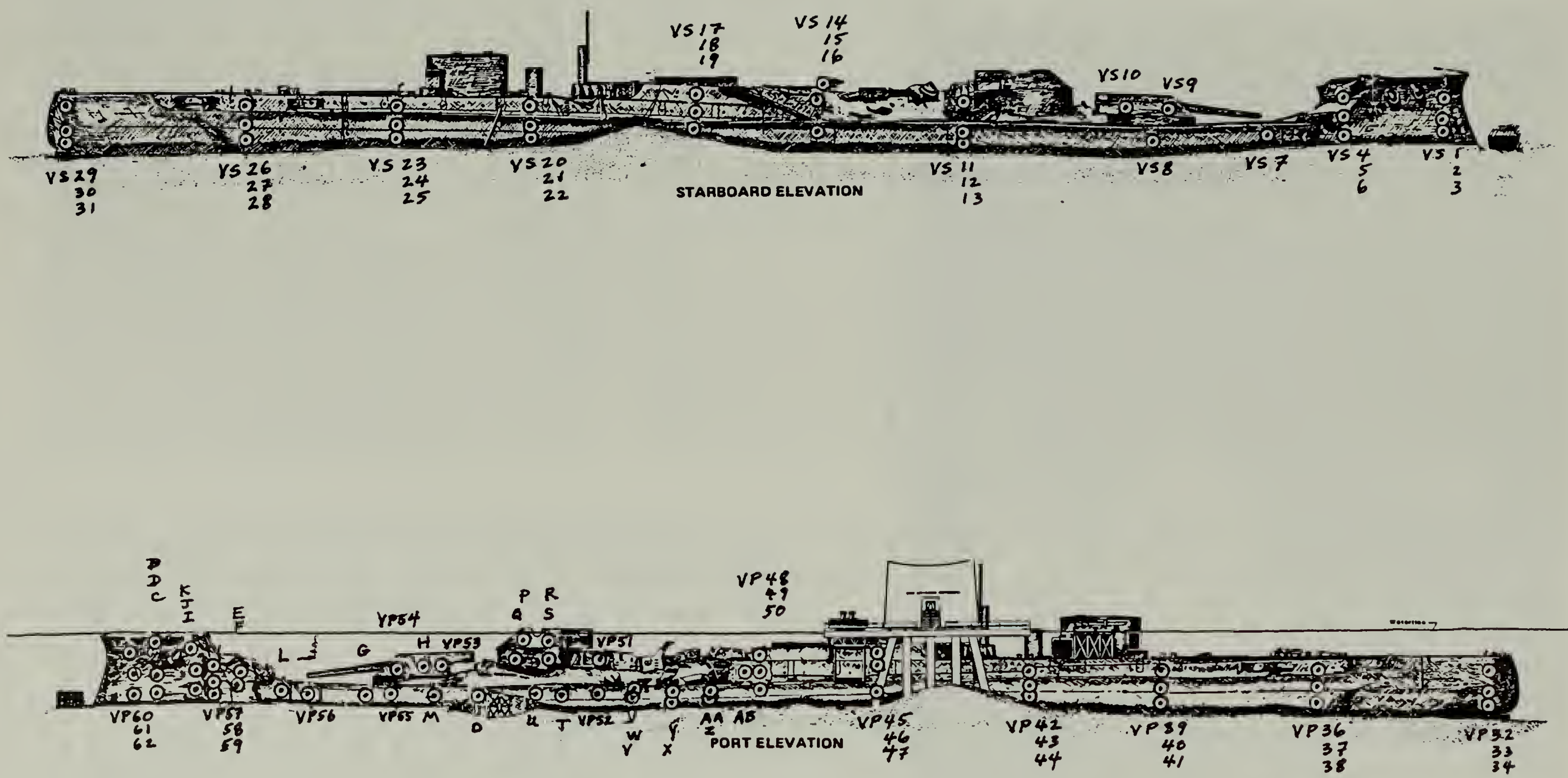


Figure 4.12. Location of bathycorrometer measurements made on the USS ARIZONA.

Figure 4.13. Scott Henderson and another diver record bathycorrometer readings. (NPS photo by Larry Murphy)

annual basis so that such an event could be detected.

6. The few areas on submerged superstructure and hull that are presently devoid of fouling should be mapped and monitored on at least an annual basis. How such areas form, and how (or if) biofouling recolonizes such surfaces, is not known at present.

7. Deck surfaces receive substantial protection from corrosion and wood-burrowing mollusks by a layer of sediment that varies considerably in thickness and composition. That layer would be expected to be less stable in the long term in shallow water, where higher water motion from waves can move sediments. Colonial feather-duster worms and sponges provide cohesiveness and stability to a large percentage of shallow sediments.

8. Sediment thicknesses on deck surfaces should be monitored on about an annual basis to determine if those layers are increasing or eroding. The status of organisms binding sediments in shallow water should also be examined periodically.

9. Fish-egg nest depressions should be monitored to determine their year-round abundance and effect on teak decomposition. If nesting activity is found to be a chronic problem, it may be possible to discourage Maomao fish (pomacentrids) from schooling and nesting in specific areas by closing off access to hatches and portholes that the fish use for protective cover. Those openings could be closed by plastic mesh glued in place with epoxy. Openings in one selected area could be closed first as a pilot experiment.

10. It was the general consensus of personnel involved in the present survey that areas where fouling growth had been removed in the course of sampling procedures should be covered to prevent rapid

corrosion of those areas. Initially, areas where biomass scrapings were made were also to be used as areas where PVC flange/studs were to be attached. However, it was found that the epoxy did not bond to clean steel underwater, and use of those areas as attachment surfaces was abandoned. It is recommended that those scraped areas be covered with thin sheets of rigid plastic bonded to dead fouling surrounding the areas.

11. Information on the amount of steel thickness remaining at nearly all accessible locations on the ship would be very useful in determining more precisely the deterioration state of the USS ARIZONA. High priority should be given to efforts to locate and test nondestructive means of determining steel thickness. Ultrasonic techniques seem to have the best potential at present. Experts on the monitoring and prevention of long-term corrosion should be located and consulted for assistance in planning future studies and preventive measures.

ARIZONA postscript 2/89

Summary of 1987 and 1988 Annual Inspections of USS ARIZONA

On September 24, 1987, two NOSC divers (biologists) performed two 45-minute dives on the USS ARIZONA. The two took close-up photographs of fouling growth at the 12 tagged vertical photo-biostations. They also measured sediment depths at 20 randomly selected horizontal stations, and made general observations on the status of fouling, sedimentation and corrosion on the ship hull.

Observations indicated no significant changes in fouling, sedimentation or corrosion, as compared to observations made during the July 1986 survey. Mean thickness of sediments measured at the 20 randomly selected stations was about 20 percent less than measurements made at the same 20 stations in 1986. However, the lower recent mean value was caused in large part by large decreases in sediment thickness at three shallow stations (No. 29, No. 52 and No. 56), where coarse, loose sediments can be readily moved into irregular mount patterns by wave action. Fish-egg nests that had been observed in abundance on the aft ship deck in the 1986 survey were reduced in abundance by about 70 percent in 1987.

The second annual resurvey was performed by the same two divers in two 45-minute dives on 29 September 1988. Photographic and observational procedures were identical to the previous survey, except that sediment thicknesses were measured at 25 randomly selected stations.

Fouling, sedimentation and corrosion observations again indicated no notable differences as compared to their status in previous surveys. Mean thickness of sediments measured at the 25 stations was 5 percent greater than the mean thickness measured at the same stations in 1986. That increase is within limits of thickness changes that would be expected to occur due to minor seasonal or annual changes in wave action and current motion.

It was noted that most of the horizontal station markers on thick mud sediments had apparently sunk into the mud and disappeared. In the course of future surveys, it would be worthwhile to replace those markers with ones of more stable design (e.g., bases with deep stakes or larger surface areas). Also, it may be necessary to use a new means of displaying station numbers on the markers, because fouling growth was beginning to fill in the engraved numbers, even though they were coated with antifouling paint.

The PVC pipe photo-studs were all relatively clear of fouling. Those had also been coated with antifouling paint, although with a thicker coating than that applied to the horizontal station markers. When visiting those stations, the growth film was gently wiped off with gloved hands.

One area of recently exfoliated hull was observed near the stern of the ship about 30 feet forward of station VS-30. That area measured about 10 feet by 10 feet, and the surrounding metal sheet had about a 1/2-inch gap between it and underlying metal. It was never resolved during the 1986 survey whether these areas are actually "delaminating" or if they are simply patches of outer hull "skin" or thin armor plate that are breaking free. Marine engineers/architects who are knowledgeable on the construction of the USS ARIZONA should be queried on the location, configuration and attachment modes of armor plate and double hull on the ship. Such information would probably be useful in furthering the understanding of exfoliation, which is clearly a major process causing hull decomposition.

Fish-egg nests were seen in very low abundance, and nearly all were on areas of sediment-free, sloping or vertical substrates. No nests had been fanned through sediment to teak deck surface, as was the case in 1986. Abundance of fish nests is likely related to seasonal breeding patterns, and to cyclical changes in overall abundance of fish resident on the ship.

All photographs (slides) taken at the photo-biostations have been retained for comparison with future photo sets to be taken at those stations.

CHAPTER V

THE MANAGEMENT EXPERIENCE

This chapter was written by two managers, Gary Cummins and Bill Dickinson, who served consecutively as superintendents of the USS Arizona Memorial from 1980 through 1988.

Introduction

The USS ARIZONA, USS UTAH and Pearl Harbor surveys, a five-year project to inventory those cultural resources, contributed to our knowledge of the historical significance of submerged cultural resources within Pearl Harbor National Historic Landmark. As a result of these surveys, managers at the USS Arizona Memorial have become aware of the unique and complex issues surrounding submerged-resource protection, and have learned how acute the need is for decisions affecting future preservation policy.

As site managers responsible for an internationally significant submerged cultural resource, we have wrestled with management decisions that had precious few guidelines and precedents. If other National Park Service managers are wrestling with similar issues and making different decisions, NPS will be perpetuating inconsistencies in management practices.

Should we be doing anything to preserve shipwrecks in place? What about shipwrecks that are also grave sites? Should we let the natural processes continue unimpaired? Should we be looking for means to slow or stop deterioration? Should we be retrieving significant artifacts? Should we, for example, remove the 14-inch guns from the USS ARIZONA so they can be displayed and people can see them before they are lost to corrosion? Should we document wrecks with known dead? Should we merely monitor the deterioration process, noting changes in conditions that occur over time but allowing deterioration to continue? Should we be diving on such submerged grave sites? Should we penetrate them? Some people argue that we are disturbing the final resting place of those who perished by diving on these wrecks. If we don't dive them, how do we learn enough to make responsible management decisions regarding health, safety and appropriate visitor use?

As we continue to study submerged cultural resources, we will gain more experience -- and answers. Equally important, we will better understand what future questions to ask.

Gary Cummins: The Project's Origins

When the National Park Service took over operation of the USS ARIZONA Memorial in late 1980, it was faced with two fundamental concerns: interpretation and management. The public was insatiably curious about the Pearl Harbor attack, but we lacked enough accurate information to satisfy this curiosity. We had wrongly assumed that the great volume of reports, surveys, eyewitness and historical accounts would enable us to answer all questions about the Pearl Harbor attack. But though we were able to handle most of the basic questions, the many gaps in the historic record left many others unanswered.

The second concern was resource management. Although the Navy actually owned the battleship USS ARIZONA, we found Navy officials relatively unconcerned about its preservation -- they had their hands full with floating ships. The public was concerned over the ARIZONA's upkeep, and furthermore believed since the National Park Service operated the USS ARIZONA Memorial, it must own the battleship. In those early days the National Park Service had very little experience in preserving large, steel, sunken ships.

Another concern relating to interpretation was the view of the American people, who perceive the USS ARIZONA Memorial less as a historic site than as a shrine similar to the Alamo or the Custer Battlefield. This pervasive view made it difficult for park interpreters to separate myth from fact, and made it especially important that all interpretive information be absolutely accurate.

After a period of time, we were able to develop an interpretive program that combined verbal presentations, a documentary film and eyewitness accounts by survivors of the attack, which answered most visitor questions. Exceptions were the many questions about the ship itself, mostly variations of "what does it look like?"

During the 40th anniversary celebration of Pearl Harbor held in Honolulu in 1981, we had an opportunity to talk with several former crew members of the USS ARIZONA and the repair ship USS VESTAL, which had been moored alongside the ARIZONA during the attack. Several told of seeing torpedo tracks streaking toward the ships, running under the VESTAL and striking the ARIZONA near the bow. These accounts were at odds with official Navy records, which attributed all of the ARIZONA's damage to aerial bombs.

The alleged torpedo tracks could have come from either torpedoes dropped by the Japanese Nakajima B5N "Kate" torpedo-bombers, or launched from the two midget submarines that penetrated the harbor during the raid. It was an interesting issue that we lacked evidence to resolve.

I began to discuss the possibility of an underwater survey of the ARIZONA with Rear Admiral Stanley Anderson, Commander Naval of the Pearl Harbor Navy Base (COMNAVBASE) and his staff. COMNAVBASE controlled the waters of Pearl Harbor, so its permission was necessary for any work there. Admiral Anderson seemed amenable, but members of his staff were aghast.

The COMNAVBASE staff, like many other Navy officers, could not understand why we would want to investigate something about which "everything was known." When we told them the things we didn't know, such as the torpedo issue, general condition of the ship, and exact location of other damage, they were still puzzled. At issue was the basic difference between the Navy's mission and methods and our own. The Navy is used to operating in a atmosphere of security that insulates much of its activity from public scrutiny, while the National Park Service seems to operate under a microscope. The Navy felt that the public had no business asking such questions, and that we could simply refuse to answer them. "Why not leave well enough alone?" was the standard response.

Finally, Navy officials were worried about the sanctity of the site. More than 1,100 sailors and marines had gone down with the ship. The idea of conducting a survey amid their remains was repugnant. One officer -- who later strongly supported the survey -- warned that "poisonous gases" trapped within the ship, possibly from the decomposing bodies of the dead crew, would have lethal effects on trespassing divers. I recognized that I had to do more homework in order to present a proposal that would satisfy Navy concerns.

We decided on an interim approach. When a new commander, Rear Admiral Conrad J. Rorie, relieved Admiral Anderson, I requested permission for Park Service divers to sweep the ARIZONA to remove the thousands of coins visitors had tossed from the memorial over the years. These coins formed an inches-deep carpet covering the ship, clearly visible from the memorial. I appealed to the Navy sense of order by pointing out that the appearance was unseemly. I added that coins containing copper tend to kill marine organisms that cover the ship with a protective coral glaze. COMNAVBASE agreed with this view, and we began "clean up" dives in early 1983.

I made the first surface dives on the ARIZONA, accompanied by Chief Ranger John Martini. Using masks, fins and snorkels, we loaded many pounds of coins into plastic buckets hung from the memorial for subsequent disposal. These coins, incidentally, became a major issue. Technically they were accountable federal property. However, when we tried to deposit the coins, banks refused to accept them. We approached the Treasury Department for advice but it never responded. As time went on we accumulated thousands of coins from all over the world, which we diligently stored in bags in the basement of the USS ARIZONA Memorial visitor center.

While gathering coins, Martini and I took the opportunity to swim over the entire ship to get an idea of its appearance and condition. The presence of silt and oil leaking from the ARIZONA's wreckage made it obvious that surface diving would not be adequate for our needs. Toward the bow, once past the remains of the superstructure and crew's galley, we could make out no more than a ghostly outline of the hull and the two main forward gun turrets. Toward the stern, in shallower water, we could brush aside silt and find the teak decking in good condition after more than 40 years.

Although the surface dives were inadequate for our needs, they did provide useful information from which to develop a broad research design for an underwater project. From the beginning I wanted to treat the ARIZONA as an archeological site, and to use archeological methodology to get at the information we needed for management needs and decisions.

In August 1982 Dan Lenihan, Chief of the National Park Service's Submerged Cultural Resources Unit in Santa Fe, visited the Arizona Memorial. It didn't take much persuasion to get him into the water on another coin expedition. After Dan's introduction to the USS ARIZONA, the concept of an underwater archeological project really began to take shape.

Dan's concept was to use terrestrial archeological methodology underwater to recover data that would meet the park's management needs and advance the science of underwater archeology. In formulating this concept, I gave Dan a list of management issues lacking data. He then developed a strategy that would meet the most rigorous archeological standards while providing the park with the needed information.

The list that I passed to Dan was as follows:

1. Overall ship condition: What does the ship look like?

   a. Battle Damage: Was the ARIZONA hit by a torpedo? If so, where? Locate bomb damage sites.

   b. Overall Integrity: How is the hull and decking holding up? Chart points of specific deterioration.

   c. Locate specific points where oil is leaking from the ship.

   d. Develop an archeological base map of the ship from which an interpretive scale model of the ARIZONA's wreckage could be manufactured.

2. Ordnance: Is there any Japanese or American unexploded ordnance on or near the ARIZONA?

To answer the Navy's (and the public's) concerns about the sanctity of the ARIZONA, we agreed that under no condition would divers enter the hull. Thus we could reassure everyone that the remains of more than 1,100 sailors and marines would rest undisturbed.

Dan also recommended that the survey be conducted over a two-year period, with the first year devoted to approximately two weeks of initial survey that would concentrate on the ARIZONA's bow section. This would permit a better estimate of the manpower, time and money needed to carry out the entire project.

When we took the refined proposal to Admiral Rorie at COMNAVBASE, we were much better received. No problems had occurred with our coin-recovery dives. Admiral Rorie and his staff were impressed with Dan Lenihan's credentials and overall approach to the project. In fact, COMNAVBASE asked us to help find a solution to its own USS ARIZONA problem!

During the 1942 salvage operation, the Navy had cut away structure from the ARIZONA and stored the pieces at a remote location within the base. Over the years, entrepreneurs had made several attempts to obtain fragments of the ship for such uses as manufacturing religious items for the tourist market. The fragments were too badly cut up and corroded for use in the visitor center museum. COMNAVBASE decided the safest course was to remove the several tons of steel from the storage site, barge them to a point near the memorial and "bury them at sea." Admiral Rorie asked if we could map a spot as near as possible to the ship where the scrap could be dumped. In return, he offered us the support of Pearl Harbor's Mobile Dive and Salvage Unit One, complete with a sizeable dive boat! We promptly agreed, and we added location of a suitable site for the ARIZONA wreckage to our list of project goals.

The Arizona Memorial Museum Association, the USS Arizona Memorial's cooperating association, agreed to underwrite the entire cost of the project, with assistance from Carol Lim, the Arizona Memorial food concessioner. Finally in the early fall of 1983 we were ready to begin a project that would provide information for our two fundamental concerns -- interpretation and resource management, while addressing our "shrine" concern by not violating the sanctity of the last resting place of the ARIZONA's crew. The rest, as they say, is history.

Bill Dickinson: Management Implications

The USS ARIZONA project began in 1983 with documentation of the 608-foot-long USS ARIZONA. Gary Cummins was site manager during the first phase of the project, until 1985. I took over from 1985 to 1988. We both felt we were operating in a fishbowl. How many times does a park manager contend with 5,000 visitors a day and the media, all fascinated with diving researchers in the waters below? The project's high visibility required intense and constant involvement of the superintendent -- it was not a task that could be kept at arm's length.

The challenge was to document in detail the remains of a battleship that was sunk over 45 years ago. Until the documentation project began, we didn't really know what was there. For example, we didn't realize there were 5-inch guns still on USS UTAH. We thought everything had been recovered during the initial salvage operations.

As a result of the work done by NPS and the Navy, the American people now, for the first time, have an accurate drawing of a highly significant historical resource that receives international attention. A detailed model created from the drawings gives memorial visitors a much better understanding of the USS ARIZONA as it exists today. The model also serves as a planning tool to assist in developing future research initiatives. In addition, we have established permanent stations on the site and collected baseline data on the ship and surrounding marine environment for longitudinal monitoring.

The drawings and model enabled us to answer many questions about the ship. We were able to determine, for example, that above the silt there are no torpedo hits on the USS ARIZONA. Speculation had said that the ship was sunk by torpedoes. We now know that there is no evidence above the silt to support that view. We also have been able to precisely identify the origin of the oil that has seeped to the surface every few minutes since the USS ARIZONA was sunk. Because the ship had been refueled shortly before the attack, the resulting oil slick has become a visual feature of the site that has been the subject of interpretation over the years.

We know the extent of corrosion, as well as the extent, density and composition of biofouling growth and silt that cover the vessel. We determined the condition of the teak deck and the location of significant artifacts that are still on the deck. We were able to determine that the 14-inch guns are still mounted on the No. 1 gun turret.

The USS ARIZONA and the USS UTAH are not just memorials, they are marine science and historical preservation "workshops" explaining the history that occurred here. They are ecological barometers over an exact period of time that can be used to track water quality in Pearl Harbor.

That portion of the USS UTAH that is above water very pointedly illustrates the rapid deterioration occurring to cultural resources in Pearl Harbor. Before long the exposed structure will be gone. Whether deterioration can ever be arrested is an open question. However, at least these structures have now been documented.

Now that the USS UTAH and USS ARIZONA have been studied, we will be able to compare two important shipwrecks in the same harbor. We will be able to study on each the biofouling and rate of corrosion, and cross-check data between the ships to see if any events are unique or similar.

Each new operation has asked and answered new questions, and developed new techniques. With the established monitoring stations on the USS ARIZONA we can record changes in biofouling. This documentation will enable us to record and monitor changes in the underwater environment that alter the rate of biofouling, which affects the rate of corrosion. We know, for example, that Pearl Harbor used to be a dumping ground for sewage. Ironically, the sewage may have contributed to the ship's preservation by creating a very fertile environment for marine growth. As a result, both the USS ARIZONA and the USS UTAH have experienced abundant biofouling growth. This same dense growth has created a thick, protective, anaerobic coating over both hulls. With reduced oxygen, underwater corrosion was significantly lessened. However, with antipollution efforts in full swing to clean up Pearl Harbor, the density of biofouling growth is decreasing. The nutrient level in the harbor is significantly lower than it was during World War II. Although cleaning up the harbor is a positive concept, it may be somewhat negative in terms of marine growth protecting the hulls. How rapidly are we losing the marine life that has helped protect the ship? Will other types of marine life appear that are equally as beneficial to the ship's fabric? Will the growth already in place be adequate, or is there a need for more? Our monitoring will help answer such questions. We plan to develop a computer model of the rate of corrosion.

During the summer of 1988, using Navy MDSU and EOD divers and submarine base support, NPS surveyed select locations in and directly outside Pearl Harbor. Although nothing of historical significance was discovered in the harbor, that negative evidence is important: We now know which areas have no significant remains above the silt, a finding that can influence decisions made in future harbor management by the Navy. During this period, the EOD team working with SCRU made a very exciting side-scan contact in the survey of the defensive perimeter outside the harbor. We established liaison with the University of Hawaii Undersea Research Laboratory, which assisted us in following up on this contact with a possible WWII Japanese midget submarine used during the Pearl Harbor attack. The full significance of that aspect of the survey is still to be determined, because at the time of this report, the contact was not confirmed.

NPS/Navy Cooperation (Project SeaMark)

With limited NPS funding and personnel to devote to the preservation of submerged cultural resources, Project SeaMark established an important precedent by allowing park managers to avail themselves of an extensive array of military assets that included people, equipment and supplies. By working cooperatively with the Navy, NPS was able to utilize both active and reserve Navy capabilities to accomplish project objectives. The Navy augmented Park Service underwater archeologists with divers primarily from the Naval reserves to assist in charting, mapping, surveying and photographing these resources.

Navy-NPS cooperation began in 1983 with active-duty divers from MDSU One and Park Service personnel. Since 1986 most Navy input has come from reservists, with less involvement by active-duty divers.

The significance of Project SeaMark is many-fold. From the broadest perspective, joint ventures like this serve national interests and, ultimately, the taxpayers. SeaMark brought together disparate federal resources to accomplish management objectives in a cost-effective manner. We took personnel and equipment resources that would otherwise have been expended on contrived Naval reserve or active MDSU training projects and assisted the Navy in redirecting those assets toward existing projects of international significance. The Naval reservists and active-duty personnel were able to simulate mobilization assignments while addressing real diving problems at real sites. They were forced to use creative approaches to overcome difficulties and successfully complete the projects. Even the logistics of moving personnel and equipment to the site was realistic mobilization training. Project participants spent much more time in the water than during a simulated exercise designed to offer the same kind of training.

The submarine base provided manpower and equipment support. The Naval Ocean Systems Center provided a marine biologist who was an expert on Pearl Harbor biofouling; the Pearl Harbor Naval Ship Yard contributed a metallurgist; the University of Hawaii contributed the resources of the Hawaii Undersea Research Laboratory (including its three-man submersible); and PACDIV provided sounding charts for Middle Loch and support of a Navy archeologist.

We have learned a great deal from these projects, and they will serve as a foundation for more productive ventures between active and Naval Reserve units, other support groups and the National Park Service.

To Preserve or not to Preserve?

The question of "to preserve, or not to preserve" underwater cultural resources has yet to be answered. Meanwhile, we are exploring methods of stabilization.

A principal reason for developing a submerged-cultural-resource management program for the USS ARIZONA and USS UTAH sites -- and Pearl Harbor in general -- is to clearly define strategies for site preservation. Options range from leaving sites alone (benign neglect) to sustaining the existing condition and integrity (preservation). A third choice is partial restoration, that is, removal of post-December 7, 1941 mooring quays, flagstaff and mooring chains. Doing nothing would, of course, eventually result in deterioration and destruction of the shipwreck.

Preservation decisions for the USS ARIZONA are complicated by a recognition that the sunken shipwreck is not only a resource of major historical significance, it is also a symbol to the American people of the beginning of World War II. Finally, it is the final place for honored war dead.

Memorial architect Alfred Preis, who was aware of the symbolic aspects of the USS ARIZONA, designed the structure to be symbolically linked to the shipwreck below. Although appropriate from a design and viewing standpoint, this linkage has become a cause for confusion for USS ARIZONA managers.

One pivotal point in managing the USS ARIZONA is determining the ship's period of historical significance. One view defines that period as a single day: December 7, 1941. Or the significant period could be considered the period from December 7, 1941 through the salvage operations, when temporary mooring quays were attached to the ship and Navy officials decided not to further salvage the vessel. But if the memorial structure is considered along with the ship, an option that we believe is inappropriate, then the entire memorialization process is also of significance. If viewed separately, should the memorial even receive consideration as historically significant? It is a unique design, but would seem of little actual historical significance in any other context.

It seems that we first need to define the memorial/USS ARIZONA relationship from a historic-preservation standpoint, then define the period of historical significance and decide whether to view it as a site or process. Once we have defined the significant period, we will be able to define the appropriate level of preservation.

The fact that the sunken ship is also a tomb containing the remains of more than 1,000 sailors and marines could be either an argument for preservation or an argument for nonintervention. The preservation view argues the need to protect the tomb's integrity, respecting it as the final resting place for so many; to allow deterioration may be considered disrespectful. The natural-deterioration view says doing anything at all would disturb the grave site, and thus be disrespectful ("these sailors and marines have been declared buried at sea so let's let them rest in peace").

Another consideration that must not be overlooked is the environmental impact of the ship's deterioration. Oil continues to leak from the ARIZONA. If the hull were to collapse, an unknown quantity of additional oil would be released. The potential for a large spill does exist.

Regardless of the period of historical significance selected and the preservation option, the authors affirm the need for a continuing research project to monitor, document, analyze and determine the type, rate and cause of deterioration. Findings and recommendations of such research are needed not only to determine the ship's present condition, but also the appropriate treatment for a historic structure, a symbol and a vault for war dead. Also needed are ongoing data returns for monitoring future deterioration and determining the existing and projected rate of corrosion. A laboratory analysis of the ship's metal will be required to make such determinations.

Other USS ARIZONA management issues that remain unanswered include: (1) What to do about the rusting remains of the USS ARIZONA's superstructure that had been removed during the salvage operations and dumped on the nearby Waipio Peninsula in Pearl Harbor? (2) What to do about the mooring quays that were attached to the partially submerged USS ARIZONA during salvage operations in Pearl Harbor? (3) What to do about the nonhistoric flagstaff attached to the ship's masts? (4) What to do about the mooring chains between the hull and the memorial dock? and (5) What to do about the USS ARIZONA's original mooring quays?

It has been suggested that the remains of the superstructure, now mostly unrecognizable, should be taken to the site and dumped alongside, because they are considered to be part of the historic scene. But there are serious questions about this course of action: The materials were never actually located alongside the ship, and to put them there would be inconsistent with the historic context. An alternative may be to identify those pieces of particular interest for display in the USS ARIZONA Memorial Museum, leaving the rest in place with the stipulation that it is available for appropriate museum display, but may not be used for commercial gain.

Action on the mooring quays, which are attached to the ship fabric, is related to the question of what historic scene should be represented? What historic period should the USS ARIZONA's remains reflect -- the period up to December 7, 1941; or including the post-December 7 activities, such as the salvage operation in Pearl Harbor, and even the USS ARIZONA memorialization process itself? A decision as to which historic period the remains should reflect permits managers to recommend removal or non-removal of the mooring quays. Any future actions on the mooring quays should be based on future research regarding the physical state of the shipwreck's fabric. As a practical matter, removal of the mooring quays may cause more structural damage to the ship than leaving them, regardless of the determined period of historical significance.

Daily raising of the American flag on the memorial honors those who fought and died. Although that flag was not a part of the December 7, 1941 historic fabric, removing it would most certainly be politically sensitive. If it is determined that the period of historical significance includes the memorialization process, then the flagstaff becomes historically significant. One must also address the flagstaff's present influence on the ship's destruction, and related safety issues. It extends 50 feet into the air and is placing a great deal of stress on the rusting mast, which eventually will fail. This is accelerating the mast's rate of deterioration as well as creating a safety hazard. If the mast fails and the flagstaff falls, it could harm visitors and cause damage to the memorial structure. Alternatives include stabilizing the ship's mast (fill it with concrete?) or removing the flagstaff. One option is to attach the latter to the memorial and extend it down to the ship's deck. Another option is to allow it to remain attached to the mast and support it with ties to the memorial.

The weight-mooring chains are causing deterioration of the historic ship fabric. However, removal may be even more destructive. An alternative is to cut the chains at the edge of the deck so the weight is eliminated. The chain on the deck would remain in place. Chain removal is directly related to the dock. Prior to any action, the importance of the chains relative to the dock would have to be determined and a replacement alternative installed.

The USS ARIZONA's original mooring quays should have a distinct preservation plan. They could be maintained as they are (with the names of the USS ARIZONA and the USS VESTAL painted on their side), restored to their original December 7, 1941 appearance, or left alone. The question of replacement, should they collapse, also needs to be addressed.

Resource-management issues can be grouped into five main categories: (1) protection of the USS ARIZONA, (2) protection of the memorial, (3) protection of historic materials/artifacts and the museum collection, (4) protection of the water area (historic zone) surrounding the sunken ship and memorial, (5) protection of resources in or close to Pearl Harbor but outside NPS operational responsibility.

Lacking both authorizing legislation and a general management plan, decisions in management of submerged cultural resources should be based on the purposes for which the park was established, as defined in the Statement for Management (August 1983):

> To preserve and interpret the tangible historical resources associated with the December 7, 1941 attack on Pearl Harbor. Of primary importance are the sunken wreck of the USS ARIZONA, which serves as the final resting place for the battleship's sailors and marines killed in that attack, and the large concrete memorial to all those killed in the attack, which straddles the ship.

The Interpretive Prospectus (October 1981), which sets the historical context for the entire park through identification of primary interpretive themes also provides guidance for resource management. The park's interpretive themes have been identified as:

1. The USS ARIZONA, its casualties and survivors;

2. The attack on Pearl Harbor; and

3. The importance of Pearl Harbor at the beginning of the war with Japan.

The prospectus continues:

> The USS ARIZONA as a historic artifact derives much of its significance in relation to the attack on Pearl Harbor and in turn on the outbreak of war. The order of thematic emphasis ensues from the nature of a memorial and the necessity of placing primary emphasis on interpretation of resources at hand.

The prospectus suggests that the appropriate historic context for the ship should center on Dec. 7, 1941, which would limit interpretation primarily to resources that are presently on site (not adding to or deleting from the historic structure).

If full preservation is to be the appropriate level of treatment, then it follows that a historic structure report for the USS ARIZONA is needed. Some of the baseline information is already in existence, derived from data obtained from recent projects run by the NPS Submerged Cultural Resources Unit between 1983 and 1988. The historic structure report is needed to evaluate the research findings and make recommendations for preservation of the USS ARIZONA.

The historic structure report should cover not only the appropriate treatment for the shipwreck itself (e.g., continued monitoring of the level and extent of corrosion/fouling, preservation techniques, and the need for a corrosion model), but should also address the need for artifact recovery from the shipwreck, and removal of the flagstaff, mooring decks, and mooring chains.

The nature and scope of the historic tructure report's recommendations will assist park managers in deciding whether a historic structure preservation guide is warranted.

The purpose of such a guide would be to direct the needed maintenance activities to preserve and protect the USS ARIZONA, both as a historic structure (shipwreck) and as a tomb for war dead. The guide would be tailored to the specific preservation needs of the USS ARIZONA, and would provide information for orderly, timely and appropriate inspection, monitoring and maintenance. The guide would also provide the means to evaluate maintenance activities to determine gaps or weaknesses and to adopt corrective measures. As additional data are obtained, modifications or additions may need to be made in the guide.

Under present CRM guidelines, possibly the USS ARIZONA can not be regarded as a historic structure and therefore preservation treatment may be inappropriate. The memorial, however, does fit the definition of a cultural resource (NPS-28, Glossary, Appendix A, page 5) and should be regarded as more than just a structure. The memorial's reason to be **is** the USS ARIZONA -- it is inextricably tied to the ship. The relationship between the memorial and the ship becomes clear when one considers the chains securing the memorial boat dock to the shipwreck and the flagstaff, which appears to be part of the memorial but is actually attached to the ship's superstructure. We need more information to determine what effect these links have on the memorial and the sunken ship.

Periodic assessment of the condition of the memorial pilings is needed. An initial inspection, conducted with the Naval Facilities Engineering Command for the NPS in 1987, suggests the pilings are structurally sound. There may be a need to develop a separate structure report and guide for the memorial, or include the memorial structure as part of the report and guide for the USS ARIZONA. Since the two structures are so different, it may make sense to deal with each separately. The guide prepared for the memorial would serve as a reference for programming routine and cyclic maintenance, including the boat dock, the pilings, and so on.

It is unclear what our role should be in the documentation and preservation of other Pearl Harbor-related cultural resources (USS UTAH, battleship row mooring quays, possible downed aircraft or sunken mini-sub). The identification and documentation of such resources would seem to be the minimally acceptable effort.

The park needs to immediately program for a research project for continuous monitoring of the condition of the sunken hull and superstructure. As soon as sufficient data are obtained, the preparation of a historic structures report should be undertaken and, assuming preservation is recommended, a preservation guide should follow.

Action Plan

The primary goal of an action plan is to develop a cultural resources management program for the USS ARIZONA battleship and memorial structure. As a follow-up to the underwater surveys of the USS ARIZONA and USS UTAH, the program should inform park managers on the status and condition of the resources, provide a long-term plan to protect and preserve the resources, and clarify specific objectives to reach these goals. The action plan should be incorporated into the overall Resources Management Plan for the park.

Objective 1

Lab analysis of metal sample from the ARIZONA's hull. Analysis should determine amount of corrosion, contributing factors, rate and corrosive nature of present condition. Will need to obtain detailed engineer drawings for the USS ARIZONA, to determine original hull thickness in various locations on the ship.

Need to develop proper procedures for removal and transport of samples for analysis (e.g., underwater epoxy that will "laminate" the metal sample prior to exposure to air/removal from existing environment). Analyze sample in lab to determine the extent and rate of corrosion.

Objective 2

Develop computer model of rate of corrosion. Project life cycle if nothing is done. Identify point of "no return" after which there would be no way to slow or stop the deterioration process.

Objective 3

Develop long-term plan for the continuous monitoring of data collection stations. Schedule dives for continuous data collection at USS ARIZONA photo stations.

Objective 4

Obtain and test equipment such as ultrasound, sonar and hologram with outside organizational support. Determine hull thickness, internal structural integrity, extent and location of internal oil/fuel reserves and projected life of hull.

Objective 5

Finish survey for the Japanese mini-sub sunk by the USS WARD. Document location and condition of submerged cultural resources as well as areas surveyed and found to be void of such resources.

Objective 6

Continue to monitor the memorial and dock, including mooring chains, pilings and memorial structure.

Identify potential long and short-term effects/impact on memorial and/or the USS ARIZONA.

Objective 7

Develop a computer map of the USS ARIZONA using data collected from dive surveys. Develop a mapping technique that can identify types of growth on the ship, and changes detected over time, where corrosion rates are highest and other relevant factors. Note deterioration and dates recorded. Photo document fabric/structural changes.

Objective 8

Analyze preservation alternatives for original mooring quays, temporary mooring quays added to the ship in 1942, chains running from the ship to the dock and the flagstaff. Decide on appropriate actions and develop plans to implement.

Objective 9

Develop position statement on the long-term disposition of the USS ARIZONA salvage materials presently located on Waipio Point. Work with U.S. Navy to implement and enforce the position.

Gary and I both believe that it is imperative to determine the historically significant period of USS ARIZONA, then to agree on what degree of preservation and monitoring the ship merits. We also need to address the question of whether the actions we could take will be more or less beneficial than allowing natural deterioration processes to continue.

CHAPTER VI

SIGNIFICANCE: Memorials, Myths and Symbols

> Yesterday, December 7, 1941 -- a date which will live in infamy -- the United States of America was suddenly and deliberately attacked by naval and air forces of the Empire of Japan . . . The attack yesterday on the Hawaiian Islands has caused severe damage to American naval and military forces. Very many American lives have been lost . . . Always we will remember the character of the onslaught against us. No matter how long it may take us to overcome this premeditated invasion, the American people in their righteous might will win through to absolute victory . . .
>
> (Franklin Delano Roosevelt December 8, 1941)

The underwater survey of the Pearl Harbor National Historic Landmark mapped and photodocumented the USS ARIZONA and the USS UTAH. The survey team also searched for a Japanese midget submarine sunk by the USS WARD in the defensive zone, Japanese aircraft, and parts from American vessels damaged or sunk on December 7, 1941. The scientific recordation of these war remains, while fulfilling a management need, also allowed archeologists to compare the physical aftermath of one of the most dramatic events in 20th-century American history to the historical record. The fabric of history could be viewed against the backdrop of contemporary perceptions and now-fading memories of the "day of infamy."

While the archeological evaluation of the Pearl Harbor attack fascinates many Americans, it is the event itself that so ingrained itself in the nation's consciousness. Pearl Harbor, particularly the USS ARIZONA, has became a national shrine. Pearl Harbor and every trace of the American forces that defended it are now imbued with an almost religious significance. As such, the ARIZONA and the UTAH, along with pieces of other battleships are relics of considerable cultural value, while artifacts associated with the attacker have their own special emotional impact for citizens of both nations. The conclusion of the Japanese attack of December 7, 1941 left behind a range of traces, artifacts and relics that form the most significant site associated with the Second World War in the United States. Pearl Harbor is one of the most emotion-laden and important war sites in the world for two generations of Americans and Japanese.

The late Gordon W. Prange, assessing the impact of Pearl Harbor, notes, "Not all the tragedy . . . could be measured in terms of lost men, ships and aircraft, nor all its glory in terms of courage, unity and the seizing of a new day. With the events of December 7, 1941, something happened to the American spirit. The flames of Pearl Harbor burned away a certain national innocence" (Prange 1986:604-605). Prange believed that Pearl Harbor's primary value lay in warning future generations about being caught unprepared and by surprise. For many visitors to the USS Arizona Memorial, the memorial is a "silent protest against smugness and unpreparedness" (Prange 1986:598).

Although cultural values are diverse and often intensely personal, certain sites carry obvious transcendent values. Decades of increasing tensions between the United States and Japan erupted in the attack on the United States Pacific Fleet at Pearl Harbor. The attack, a tactical coup for the Japanese, followed their longstanding tradition of surprise attack. To many Americans, the surprise and shock of suddenly being plunged into a world war after two decades of isolationism was a brutal awakening. It was attended by horror at American unpreparedness, the near destruction of the battleships of the Pacific Fleet, and the death of thousands of servicemen and civilians. Almost any American not an infant on December 7, 1941 remembers with clarity where they were and what they were doing when the news of the attack was flashed to an unsuspecting nation. Shock turned to indignation, then rage, and finally a steely determination to wage total war. The slogan was "Remember Pearl Harbor!"

The United States Naval Base, Pearl Harbor, was designated a National Historic Landmark in 1965 because of its role in American expansion into the Pacific. Although still an active naval base, the harbor is prominent because the United States recognizes the importance of those historic events. The attack of December 7, 1941 was one aspect of the base's history and significance. In 1978 further study of the Pearl Harbor National Historic Landmark indicated that specific aspects of the attack deserved additional attention and designation, and a number of nearby sites including Wheeler, Kaneohe and Hickam Field were designated National Historic Landmarks on the basis of their roles on December 7, 1941. These designations were part of a larger study of sites associated with the War in the Pacific specially requested by Congress and prepared by Historian Erwin Thompson. As part of that study, a number of vessels that served in the War in the Pacific were separately evaluated by National Park Service historian Harry A. Butowsky. Butowsky's "warship" study identified more than 25 vessels, including aircraft carriers, battleships, destroyers and submarines. On January 22, 1984, 21 of those vessels were designated as National Historic Landmarks, including the submarine USS BOWFIN, on display at Pearl Harbor (Butowsky 1985).

No vessel present at Pearl Harbor on December 7, 1941 became a National Historic Landmark until recently. Of 97 U.S. vessels present at Pearl Harbor, and of the 31 Japanese vessels deployed in the "Hawaii Operation," only two American and two Japanese vessels are known to survive.

The United States Coast Guard cutter TANEY is now a museum ship in Baltimore, Maryland; the only surviving U.S. Naval vessel left afloat is the former yard tug HOGA (YT-146), now the fireboat CITY OF OAKLAND, in Oakland, California; and two Japanese midget submarines lost during the attack. HA. 19, a midget submarine that washed ashore at Bellows Point on December 8, 1941, was exhibited in Key West, Florida, after the war. Another midget, discovered sunk in 1960, was raised and returned to Japan. It is a memorial on display at the Japanese Naval Academy at Eta Jima.

Of the other vessels present that day, all were removed except two: the USS ARIZONA and the USS UTAH. Some of these vessels exist as shipwrecks elsewhere. Of these, only the wreck of the USS PENNSYLVANIA -- the ARIZONA'S sistership and the flagship of the Pacific Fleet, which was slightly damaged in drydock at Pearl Harbor -- lies in deep waters off Kwajalein, where it was sunk after postwar weapons tests. TANEY was designated a National Historic Landmark on January 27, 1988. HOGA and HA. 19 were assessed in late 1988 and designated NHLs on June 30, 1989. Another Japanese midget submarine may have been located in 1988 during the NPS/Navy submerged cultural resources survey.

The sunken hulks of the USS ARIZONA and the USS UTAH were merely mentioned in the initial National Historic Landmark documentation of Pearl Harbor. The 1978 NHL reassessment determined that the two vessels, as well as their memorials, were contributing elements to the NHL. The two hulks were not assessed or documented under the criteria of the National Historic Landmarks program until 1988, following five years of archaeological documentation. Substantially intact, the USS ARIZONA and the USS UTAH were nominated on July 9, 1988 as properties of exceptional national significance worthy of individual designation as National Historical Landmarks. On October 24, 1988, the National Park System Advisory Board, meeting in New Orleans, reviewed the studies and formally recommended them to the Secretary of the Interior for NHL designation. Both the USS ARIZONA and the USS UTAH were designated National Historic Landmarks by Secretary of the Interior Manual P. Lujan on May 5, 1989.

The Secretary's designation recognized the ARIZONA's exceptional national importance, both as a historical property and as a national shrine. The battle-scarred remains of the submerged battleship are the focal point of a memorial erected by the people of the United States to honor all American servicemen killed on December 7, 1941. The ARIZONA's burning superstructure and listing foremast, photographed in the aftermath of the attack epitomized to the nation the words " Remember Pearl Harbor," and is one of the best-known images of the Second World War in the Pacific. One war poster graphically presented the image of the shattered, burning ARIZONA, exhorting viewers to "Avenge December 7" while a seaman shook an angry fist (Figure 6.1).

The USS ARIZONA and the Arizona Memorial have become a major shrine and point of remembrance not only for the lost battleship but also for the entire attack. The explosion that destroyed the ARIZONA shook the harbor, blew debris and parts of bodies for thousands of feet. It was the central event of the attack and remains central in the reminiscences of most survivors. Indelibly impressed into the national memory, the ARIZONA is visited by millions who quietly file through, toss flower wreaths and leis into the water, look at the rusting hulk through the oil-

Figure 6.1. This war poster illustrates the role of Pearl Harbor as a national symbol used in accelerating the war effort. (NPS photo)

stained water, and read the names of the dead carved on the marble plaque attached to the memorial's walls. Perhaps more important than the modern memorial that straddles ARIZONA is the battleship itself, which is the ultimate shrine. Resting in the silt of Pearl Harbor, the USS ARIZONA is a naval memorial and a war grave. It was the scene of tragedy, triumph and heroism. The wrecked ARIZONA is also a crystallized moment in time, its death wounds visible and still bleeding oil, the intact hull holding most of the crew.

The wreck now serves as a "temporal touchstone," drawing visitors who reflect on the tragedy of the Pearl Harbor attack: the loss of many of the ARIZONA's crew and more than a thousand other Americans on December 7, 1941, and the heroism of those who died defending their country. Among the honors awarded to Pearl Harbor survivors and victims were sixteen Medals of Honor, 48 Navy Crosses, 7 Distinguished Service Crosses, one Army Distinguished Service Medal, 1 Navy Distinguished Service Medal, 3 Legions of Merit, and hundreds of commendations (Ross and Ross 1988).

The other victim of the attack still left at Pearl Harbor, the USS UTAH, was also designated a National Historic Landmark. Less known than the ARIZONA, the UTAH has been called the "forgotten victim" of Pearl Harbor. The UTAH was not an intended target of the Japanese, and the mythology is incorrect that says the former battleship turned target ship was sunk after a mistaken identification as an aircraft carrier. The UTAH did not explode dramatically. Torpedoed, it capsized, killing 64 of its crew. Chief Watertender Peter Tomich stayed at his post and helped save other men's lives by laying down his own, posthumously winning the Medal of Honor. After unsuccessful attempts at salvage, the outdated target ship was left as a tomb for 58 members of its crew behind Ford Island. Neglected, the UTAH was recognized with its own memorial in 1971. Although its sinking did not capture the public imagination like the ARIZONA, the target ship was by far the more historically significant at the time of sinking.

The UTAH's career as both a battleship and target ship spanned three decades and included nationally significant service with international implications. The UTAH was the primary U.S. warship involved in the American landings at Vera Cruz, Mexico in 1914 and participated in the First World War. Its alteration from battleship to target ship because of conditions of the Washington Naval Treaty of 1922 was part of a program that had considerable impact on the U.S. Navy, as well as many other nations' navies. Ironically, Japanese anger over what they perceived to be unfair treaty ratios contributed to the war that followed. As a target ship, the UTAH trained naval gunnery and bombing crews. Its use as a platform for antiaircraft weapons was of particular importance: Many of the gunners who shot down Japanese aircraft in the opening stages of the war were trained aboard the UTAH. The intact battleship's hull, still armed with 1941 state-of-the-art antiaircraft weapons, is a unique, well-preserved entity with considerable architectural integrity. Grouped with the National Historic Landmark battleship USS TEXAS (1913) at San Jacinto, Texas and the ARIZONA, the UTAH (1909) is one of only three surviving pre-WWII American super-dreadnoughts. The three battleships recall an earlier arms race when power was measured in battleship tonnage and the diameter of shells in a ship's main battery of guns.

The significance of the ARIZONA, also a World War I participant, clearly focuses on the events of December 7, 1941 and its aftermath. "ARIZONA is best remembered for the nature of her loss, perhaps the worst single naval disaster in our history, and certainly the best known symbol of the attack on Pearl Harbor" (Friedman et al. 1978:39). Thus it is fitting that it be the focal point of memorialization and remembrance. The ship is the basis of a special type of memorial that focuses on ultimate victory against initial bad odds, on death not in vain, of sacrifice and honor. A malleable symbol, a national shrine and a historic property, the USS ARIZONA's significance is not that of a historic vessel, as is the UTAH. The significance of the ARIZONA more closely relates to its status as a naval memorial, a war grave and a national symbol.

The USS ARIZONA as a Naval Memorial

The concept of naval memorials is an ancient one. Naval memorials can be prizes of war: the flags, weapons or vessels of the enemy. War prizes, for the most part, have focused on the preservation of vessels as trophies. Octavian, following his victory over Antony and Cleopatra's fleet at Actium, erected a memorial on the hill overlooking the battle site adorned with the bronze rams from the prows of dozens of captured ships (Murray and Petsas 1988). Just as the Romans paraded captured generals and troops through the streets of Rome, other victors have exhibited the captured vessels of an enemy.

In the United States, German U-boats taken as reparation after the First World War were displayed along the Atlantic seaboard. The Japanese midget submarine HA. 19, captured at Pearl Harbor, was toured around the country on a drive to sell war bonds. The German submarine U-505, captured at sea by a Naval task force in the first open seas capture of a prize by the Navy since the War of 1812, toured ports selling war bonds after VE day. HA. 19 was exhibited as a trophy of war at the U.S. Submarine Base, Key West for many years, as was the case with other midget Japanese and German submarines at Pearl Harbor, the sub base at Groton, Conn. and the Washington Navy Yard. U-505, dedicated as a memorial to servicemen who lost their lives to U-Boat attack in the Battle of the Atlantic, is a Naval memorial displayed at Chicago Museum of Science and Industry and has been designated a NHL.

Other naval memorials of a similar type exist in the world. The Peruvian monitor HUASCAR, captured by Chile in the War of the Pacific in 1879, is now a memorial after years of use by the Chilean Navy. A more recent prize, the USS PUEBLO, is displayed by its North Korean captors. For the most part, though, captured enemy vessels are not made into memorials -- most are turned against their former owners and are integrated into the victor's fighting force. This practice was commonly followed by the Royal Navy and almost every other naval power well into modern times. During the American Civil War, both Union and Confederate fleets were augmented by captured vessels.

The more common form of naval memorial is the preservation of portions of a ship or the entire vessel. This happens when the ship has served long and well, fought victoriously in a particular battle or battles, or is perceived as being a ship that enhanced the national cause. The British preserved Drake's privateer GOLDEN HINDE after his epic 1579 circumnavigation and "singeing" of Philip of Spain's beard through attacks on Spanish shipping in the Pacific. The most famous British naval memorial of all is HMS VICTORY, Lord Nelson's flagship at Trafalgar, the epic sea battle of the Napoleonic Wars. Since the 1920s, the VICTORY's hull has been displayed in drydock at Portsmouth Naval Shipyard. Its American counterpart is the USS CONSTITUTION, "Old Ironsides," preserved for its role in the War of 1812. At Yokosuka, Japan a museum displays the cruiser MIKASA, flagship of Admiral Togo when he smashed the Russian fleet at Tsushima in the decisive sea battle of the Russo-Japanese War of 1904-05. Another famous American Naval memorial is the cruiser USS OLYMPIA, flagship of Commander George Dewey when he sank the Spanish fleet, without loss of American life, at the Battle of Manila Bay in May 1898. The spot where the admiral stood and supposedly said, "You may fire when ready, Gridley," is marked with footsteps of engraved brass. In the Soviet Union, the cruiser AURORA, whose guns heralded the attack on the Winter Palace during the Bolshevik revolution, is displayed at Leningrad (then Petrograd) (Brouwer 1978).

Currently more than 40 naval vessels rest on display in the United States as war memorials. The majority are World War II vessels. The status of "Naval memorial" has not always guaranteed the continued display or preservation of many vessels. The battleship USS OREGON, contemporary of the USS OLYMPIA, was taken from display at Portland, Oregon, partially scrapped during World War II, turned into an ammunition hulk, and then completely scrapped after the war (Sternlicht 1977). The USS HARTFORD, Admiral David G. Farragut's flagship from the battle of Mobile Bay where he defiantly damned the torpedoes, sank from old age and was broken up by the Navy in the late 1950s. Most recently the USS MISSOURI, the battleship on whose decks the Japanese surrender was signed, was taken off display at Bremerton, Washington, refitted and returned to active duty. Others have been resurrected from the bottom to serve as memorials. The brig NIAGARA, Oliver H. Perry's flagship from the Battle of Lake Erie, was raised in 1913 during the battle's centennial, rebuilt and displayed afloat and ashore until recently. The rotted hulk was rebuilt and relaunched in 1988.

Considerable attention has also been paid to the ironclad USS MONITOR, similar in many ways to the ARIZONA. Both wrecks fit the assessment of significance offered by Dr. Larry Tise for the MONITOR, which he described as "a part of the American mind, its bare mention conjuring up images of what we are as a people, of our experience as a people, and of some of the major events and motifs of our history" (Tise 1978:13). The MONITOR's remains, located by archeological survey in 1973, have been the focus of debate for more than a decade - debate over what to do with the ironclad hinges, not on managing the vessel as a shipwreck, but on full or partial recovery. The MONITOR was the first shipwreck designated a National Historic Landmark in the United States, the ARIZONA was the second.

The two wrecks were designated for the same basic reason -- their mythic quality. Myths are stories, recurring themes or archetypal characters that appeal to people's consciousness by embodying cultural ideas or expressing deep, commonly felt emotions. The MONITOR became part of American myth and culture because of its much-publicized battle with CSS VIRGINIA (MERRIMACK) at Hampton Roads during the Civil War. "MONITOR's impact is reflected in the popular culture of its era; cartoons, poems and other forms of social expression of the 1860s are replete with MONITOR references. A hero-cult was attached to the vessel's designers and officers, and MONITOR instilled a sense of American technological know-how and might" (Delgado 1988:1). The ARIZONA is also mythic. The devastation wrought within a matter of minutes to ARIZONA epitomizes the entire attack on Pearl Harbor. The ARIZONA's image was the one most recalled during the national desire to "Remember Pearl Harbor" while the war raged. The loss of its crew and the heroism of the living resulted in a more modern hero cult as seen in the unique social status and veneration of Pearl Harbor survivors and the Navy's own response to ARIZONA's "twisted hulk." Rear Admiral Isaac Kidd Jr., whose father died aboard the ARIZONA, doubtless spoke for many others in the Navy when he stated that during the war ARIZONA served as a "monument to valor," a grim reminder to active units of the fleet as they left Pearl Harbor that their mission was always to "seek out and destroy the enemy" (Friedman et al 1984:n.p).

The ARIZONA is the nation's only major naval memorial vessel associated with disaster. Although destruction of the USS MAINE propelled the nation into war in the last century, only pieces are displayed (the ship's foremast marks the graves of the ship's crew at Arlington; (Figure 6-2) the MAINE's shattered hulk was retrieved from La Habana Harbor and sunk in deep water in the early 20th century). Other sunken warships lie unmarked in the ocean, with plaques ashore, commemorating their memory, crews and loss. The USS ARIZONA serves as a naval memorial in large part because of its accessibility. Admiral Kidd noted that the battleship is the only warship lost during World War II whose wreckage still remained in sight when the war was over; all the others went down in deep water and "their bones rest in unknown lands beneath the sea" (Friedman et al. n.p). The UTAH also remained in sight at war's end, but not in the public eye. The ARIZONA's extraordinary sacrifice, its unique national exposure, and its continued visibility after the war made it a unique naval memorial.

The USS ARIZONA as a War Memorial

As early as during the war, the Navy discussed plans to make the ARIZONA's visible remains a war memorial. Even then, divergent views on a memorial's nature and purpose reflected the mythic quality of the ship and its symbolism. While ultimately the ship was to serve as a war grave, it was the primary interest of the U.S. Navy to memorialize the ship as a "Navy obligation to what had been one of the fleet's proudest ships and the sailors who went down with her" (Slackman 1984:47). The ship itself, while a naval memorial and war grave, is not the war memorial. That distinction belongs to the concrete arched structure that spans the sunken hulk but -- symbolically -- does not touch it. The sunken ship is the artifact and reminder of December 7, 1941. As such, it is a potent symbol that is enhanced and interpreted by the memorial structure. The 1962 memorial, supposedly dipping in the middle to symbolize the initial low point of U.S. fortunes after the attack and rising at both ends to symbolize the nation's rise to victory, is less a memorial to the ARIZONA than it is to the great experience of American World War II. Architect Alfred Preis:

> . . . viewed the United States as an essentially pacifistic nation, one that inevitably would sustain the first blow in any war. Once aroused by that shock, the nation could overcome virtually any obstacle to victory. Because of that characteristic, it was unavoidable -- even necessary, in Preis' view -- that this nation suffer the initial defeat at Pearl Harbor. He meant his design for the memorial to be a reminder to Americans of the inevitability of sustaining the initial defeat, of the

Figure 6.2. The Battleship MAINE disaster is memorialized at Arlington National Cemetery. (NPS photo by J. Candace Clifford)

potential for victory, and the sacrifices necessary to make the painful journey from defeat to victory

(Slackman 1984:74).

The war memorial's basic message meets Preis' intent. The ARIZONA's loss serves as a vehicle for personal reflection on war's causes, conduct and results. When the shock and initial anger of December 7 had diminished, the ARIZONA transmuted to a symbol of what could happen if the nation were again caught unaware. The battleship stood for the need for military preparedness, for not underestimating potential foes, for alertness, and for mutual understanding and respect (Prange et al. 1986:629).

The ARIZONA as a War Grave

The USS ARIZONA is a war grave, in addition to being a naval and war memorial. These values are closely interrelated and complementary. The greatest single loss of life at Pearl Harbor (and in United States naval history) came when the ARIZONA's munitions exploded, killing 1,177 of its crew. The collapse of the vessel's forward sections and the intense heat of the blast and the fires that followed made recovery of only a few bodies possible. Given the nature of the destruction, possibly only a few others would have been recovered even if the battleship had been raised and systematically dismantled during the war. Thus the ship became a tomb for hundreds of its crew. The men aboard were declared buried at sea. Now the ship serves on occasion as the burial site for survivors who in recent years have had their remains interred in the No. 4 turret's barbette.

Other burial places of servicemen killed in action have become national memorials and shrines. Many Civil War parks in the National Park System first were designated as national cemeteries. Another memorial to military defeat and disaster is Custer Battlefield. Recent archeological work has indicated that the battlefield contains scattered remains from the men of the 7th Cavalry (see Figures 6-3 and 6-4). Blood-shedding to protect an ideal or defend a nation is a sanctified ritual that creates "hallowed ground." Gettysburg is a prime example of this phenomenon. It is also for this reason that the ARIZONA is first and foremost a reminder of December 7, 1941. Without the dead aboard, the site would be less compelling -- empty memorials do not have the drawing power of tombs. The desire to visit the graves of famous and noteworthy dead is strong, and reaffirms common cultural bonds and ties. Humans seem to possess an inherent need to confront their own mortality, and visiting a war grave provides a means for doing so.

Although sunken naval vessels lost in battle in the deep sea are considered worthy war graves, the rusting, visible hulk of the USS ARIZONA was not unanimously regarded as appropriate for a final resting place for its crew. However, wartime priorities, the difficulty of salvaging the vessel and recovering the bodies resulted in most of the dead being left on board. As early as 1955, the commander of the 14th Naval District (headquartered at Pearl Harbor) wrote the Secretary of the Navy of his determination that the Navy do something with the wreck because "this burial place for 1,102 men is a rusted mass of junk . . . an appropriate memorial should be constructed . . . " (Slackman 1984:57). The continued existence of the ARIZONA as a visual vault for the dead was disturbing to others. Proposals ranged from dismantling the ship and burying the dead with other war losses, including other Pearl Harbor dead, at National Memorial Cemetery of

Figure 6.3. Survivors of the Little Big Horn (Reno Benteen Battlefield) and wives pose at Custer Battlefield in 1886. photo by D. F. Barry. (Custer battlefield N.M. collection)

Figure 6.4. Modern view of Custer Battlefield, one of the few U.S. memorials to military defeat. (Custer Battlefield N.M. collection)

the Pacific to burying the ship beneath landfill.

The memorial, originally intended for the ARIZONA's dead, became a statement on war, with the ship and its crew serving as a metaphor. The original design concepts of Alfred Preis were reflective of the site as a grave. In 1950, Preis had envisioned a floating "eternal flame." The design he submitted for the actual memorial was similar to European crypts visited by Preis in his youth. It included a submerged viewing chamber open to the sky with portholes where visitors would "view the underwater remains of the ship, encrusted with the rust and marine organisms that reminded the architect of the jewelled imperial sarcophagi" (Slackman 1984:73). That design, with its stark confrontation of death, met with a lack of enthusiasm from the Navy. Preis designed the present memorial with its emphasis as a war memorial inspired by, but not confronting, the reality of the ARIZONA's destruction and sinking. While the plaque inside the memorial and the ARIZONA's bell commemorate the ship, the basic purpose of the memorial itself, as decreed by Congress and designed by the architect, is (as per Public Law 87-201, the authorization of funds for the memorial in 1961) "in honor and commemoration of the members of the Armed Forces of the United States who gave their lives to their country during the attack on Pearl Harbor, Hawaii, on December 7, 1941."

Unresolved questions about the ARIZONA's loss, as well as the desire to seek and identify submerged "relics" from the attack, not for recovery but for archeological study, were factors in the National Park Service decision to conduct research dives on the ships ARIZONA and UTAH, and the area of Pearl Harbor. However, as the first NPS superintendent of the memorial noted, "Visitor curiosity first spurred our need to learn more about the battleship" (Cummins 1984:4). Interest continues to focus on the raison d'etre: the ARIZONA.

Archeological and Anthropological Values

Some people may be critical of studying archeology of the recent past, particularly for a subject as well-documented as World War II. Archeology, after all, is often viewed as the recovery of lost or forgotten information from the distant past. In truth, archeology actually functions as a scientific tool to extract meaningful information about human behavior from the material record regardless of age. Given an event of the magnitude and emotional impact as Pearl Harbor and the ARIZONA's loss, perceptions and memory -- even the historical record -- are clouded by what the participant or historian chose to see or thought they saw. People see the same event differently, based on their unique psychology and experiences prior to the event. While archeologists suffer from the same "behavioral baggage" in their analysis, they work not from imperfect memory and selective documentation but rather from the wide range of physical remains of an event. The study of the ARIZONA and other sunken remains from December 7, 1941, offers not only first-level impressions of what happened and what survives, but also provides the means for assessing reality against perception and accounting for the differences in human behavior. Hence, the archeology of Pearl Harbor is a laboratory for analyzing society's myths, symbols and images -- the expression of what makes people what they are.

At a different level, the archeology of Pearl Harbor is the means for anthropological assessments of the ships, the crews and the events of December 7, 1941. There can even be anthropological assessment to the reactions of people to the archeological study. That the ARIZONA is indeed a very sacred place in American culture is evident in the decision not to enter the wreck and disturb human remains. The ship presents a unique archeological situation, different from dealing with older human remains, such as Custer's men, Indians, or even the enemy's dead from the Second World War. A variety of reasons -- respect, concern for living relatives, and propriety -- come to mind, but these reflect our cultural beliefs as Americans at this place and time. Other war dead are actively sought, forensically identified and reburied in cemeteries. The United States Army runs the Central Identification Laboratory (CIL) in Honolulu. Primarily created to recover and identify the remains of some 2,500 Americans presumed killed in Vietnam, CIL expanded its mission in the 1970s to include the remains of Americans lost in the Pacific during World War II. The best known CIL case dealing with World War II casualties involved the recovery of 22 men's scanty remains from the wreckage of a B-24 bomber lost on the Owen Stanley Range of New Guinea. CIL's forensic anthropologist, Tadao Furue, analyzed shattered bones and teeth to amazingly provide each "body" with a name. The remains were returned to their families more than 40 years after they died, and the pilot, Robert Allred, is buried in the national cemetery in Oahu's Punchbowl (Sheehan 1986). The ARIZONA's dead are "buried at sea." Yet Japanese families seek remains of their dead, even from sunken ships, and cremate them with due ceremony. This example provides a contrast to the ARIZONA, indicates how basic cultural behaviors and values are represented in the design of the study.

If the remains of Pearl Harbor dead are sacrosanct, the physical remains of ships and aircraft are not. Artifacts salvaged from the ARIZONA are scattered around the United States like holy relics. The silver set resides in Arizona's capitol building, while one of the ship's bells rests on a pedestal in the memorial. An anchor from the ship adorns the entrance to the visitor center ashore. Fragments and instruments from Japanese planes shot down during the attack are displayed at Pearl Harbor and elsewhere in the United States. The discovery of other Pearl Harbor "relics" have resulted in their recovery from the bottom in the past, most notably a midget submarine recovered in 1960. Public interest was highest in the submerged cultural resource assessment when items that potentially could be recovered were found, notably again a midget submarine. But when a particular "artifact" could not be recovered, the capturing of images on video in drawings resulted in peaks of public interest. The maps and drawings of the ARIZONA impart a fuller sense of what lies beneath the oil-soaked waters of the harbor, and are eagerly sought. Similarly, the scale model of the wreck intrigues visitors who seek more than glimpses from the memorial.

The Symbolic Value of the USS ARIZONA

The USS ARIZONA is the major focal point for visitors to Pearl Harbor. There has been some discussion of whether interest in World War II sites will diminish when the last of the combatants are gone. Such was not the case with the Civil War, as attested by a host of sites, museums and books. The interest in the ARIZONA might decline in future generations, but the basic purpose of the memorial and its dependence on the ship probably make that unlikely. As a naval memorial, the ARIZONA will always be the subject of honor and reflection by the US Navy. To other Americans, the ship and its memorial will continue to be a major American shrine, for it reflects the basic truths of how we perceive and deal with war. It remains a potent symbol, meaning many things to many people. For those survivors of the event, and for the families of those dead entombed in the ship, the ARIZONA is a place to come to confront the past and perhaps come to terms with it.

For many Americans alive on December 7, 1941, Pearl Harbor was a symbol of the nature of the enemy they fought. Propagandists often employ emotion-laden terms, and for war-generation Americans, Japanese military conduct is summed up in phrases like "Rape of Nanking," "Pearl Harbor" and "Bataan Death March." (Dower 1986:28) For some people the ARIZONA symbolizes the character of the enemy attack. While the Japanese were castigated for a "suicide" mentality during the war, particularly Kamikaze plane attacks, Americans also honored the same ideal. Historian John W. Dower notes that "On the eve of Pearl Harbor, one of Hollywood's most popular offerings was They Died With Their Boots On, an Errol Flynn movie commemorating Custer's Last Stand" (Dower 1986:12). For some, then the ARIZONA is a symbol speaking to those values, much like Custer Battlefield or the Alamo. The issue of Japanese "infamy" and "perfidy" will probably ultimately fade. The universal concept of sacrifice and honor of those who died for an ideal will not.

Another part of the symbolism of the USS ARIZONA is the link to the sentiments evoked by the discovery that "our flag was still there." From the star-spangled banner of Fort McHenry to the torn, stained flags of the warships at Pearl Harbor that remained flying even on mostly sunken ships, the image of our flag flying through fierce enemy attack is a cherished notion. The park's discussion paper for a cultural resource management plan notes that "the flagpole/raising of the American flag [on the ARIZONA] is a symbol of America's freedom. It honors and recognizes those who fought and died so that it may continue to fly."

The ultimate symbolism of the USS ARIZONA and the memorial, however, is the basic perception of war and its conduct. To many Americans of an older generation, the ARIZONA, the national symbol of the Japanese attack on Pearl Harbor, also symbolizes the need for preparedness, for military strength, and for alertness. It is also an object lesson for those who vow "never again." It is ironic that the memorial was authorized and built during the Cold War, and thus invoked as a symbol for that day and age:

> . . . it is imperative that we be prepared either to win a war against Godless communism or prevent such a war by being so strong that the dictators in Moscow will be afraid to drop the first bomb. It is therefore, appropriate that, through this memorial, we focus our attention on our most striking example of unpreparedness, so that we may be perpetually reminded of the security that is found in strength.
>
> (Sen Carl Hayden of Arizona, as quoted in Slackman 1984:60).

To a later generation that fought in Vietnam or protested the war, the ARIZONA has been seen as a memorial to the futility of war and the inevitability and finality of death brought by the use of force between nations. Whatever the perception, however, the ARIZONA is a symbol, and the ultimate significance of the vessel and its memorial lies in the ability to be all things to all people. The ARIZONA and the events of December 7, 1941, continue to reflect cherished stories, cultural values and beliefs, not only of Americans but of people from other lands and cultures as they also confront the face of war.

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