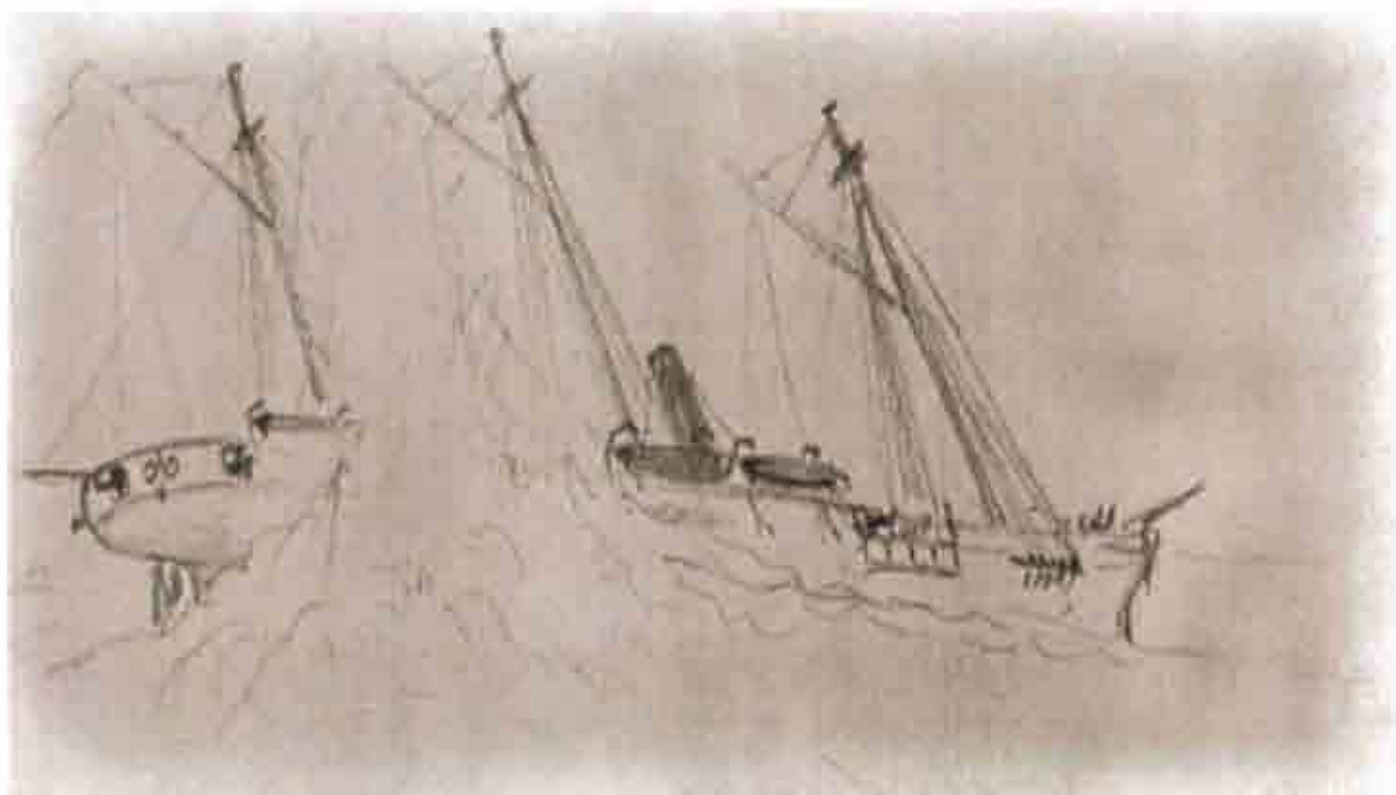


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USS HOUSATONIC

SITE ASSESSMENT



NATIONAL PARK SERVICE
NAVAL HISTORICAL CENTER
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January 24, 2006

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Dear Technical Information Center:

Please accept with our compliments the enclosed volume entitled: *USS Housatonic: Site Assessment*, edited by David L. Conlin, Submerged Resources Center Professional Papers Number 19, Naval Historical Center Underwater Archaeology Branch Professional Papers Number 4.

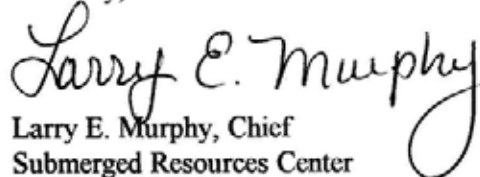
This monograph presents research done in 1999 on the wreck of the Union blockade vessel *USS Housatonic* by the National Park Service, Naval Historical Center and South Carolina Institute of Archaeology and Anthropology. In addition to these three principal agencies, many others also contributed to this broadly interdisciplinary, minimum-impact examination of the site.

USS Housatonic was sunk off Charleston, South Carolina, by the Confederate submarine *H.L. Hunley* February 17, 1864. This was the world's first successful attack by a submarine in combat.

This study demonstrates the value of a science-based interdisciplinary approach and interpretation in a broad context. It should be of interest to archeologists, managers and the general public.

As always, we welcome your comments.

Sincerely,


Larry E. Murphy, Chief
Submerged Resources Center

Enclosure



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IN REPLY REFER TO

5000
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Dear Colleagues:

It is with great pleasure that I send you the enclosed volume: *USS Housatonic Site Assessment* produced as a collaborative effort between the National Park Service Submerged Resources Center and Naval Historical Center Underwater Archaeology Branch.

In 1999, archaeologists from the Naval Historical Center, National Park Service, and South Carolina Institute of Archaeology and Anthropology documented the wreck of the Union blockade ship *USS Housatonic*. *Housatonic* became the first victim of submarine warfare, when it was attacked and sunk by the confederate submarine *H. L. Hunley*.

The archaeological research conducted on *Housatonic* and continuing with *Hunley* illustrates the significant contributions that professional archaeology brings to this specific naval engagement and Civil War shipwrecks in general. In addition to providing essential research to the battle between *Hunley* and *Housatonic*, the 1999 survey project provided a training ground for the same archaeologists who in 2000 raised *Hunley* and brought her safely to shore.

Sincerely,

ROBERT S NEYLAND, Ph.D.
Branch Head
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USS *HOUSATONIC* SITE ASSESSMENT

a cooperative project of

National Park Service
Naval Historical Center
South Carolina Institute of Archaeology and Anthropology

funded by

Department of Defense Legacy Resources Program
Friends of the *Hunley*
Systemwide Archeological Inventory Program

a collaborative product of

National Park Service
Submerged Resources Center
and
Naval Historical Center
Underwater Archaeology Branch



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1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes that this is crucial for ensuring transparency and accountability in the organization's operations.

2. The second part of the document outlines the various methods and tools used to collect and analyze data. It highlights the need for consistent data collection procedures and the use of advanced analytical techniques to derive meaningful insights from the data.

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and *Housatonic* and donated time and expertise to the project. The successful recovery of *Hunley* in the summer of 2000 was due in part to their analysis of the geotechnical characteristics of the sediment matrix surrounding the submarine.

Geologist Lou Silverman contributed time and expertise to review materials included in Environmental Context (Chapter 8).

Tina Haddon, Mark Purcell and Robert Riggs from the Regulatory Branch of the US Army Corps of Engineers, Charleston District, assisted the project immensely by ensuring that all permits were correctly completed prior to the initiation of fieldwork.

National Underwater and Marine Agency (NUMA) Archeologist Ralph Wilbanks first suggested systematic jet probing of the *Housatonic* site and offered practical advice for offshore operations based on years of experience. Archeologist Wes Hall provided background material from the NUMA examinations of the *Housatonic* wreck and suggestions for further research.

The US Coast Guard Group Charleston in general, and Commanders Frank Sturm and Peter DiNicola in particular, assisted the project with enthusiasm and impeccable professionalism.

Personnel from NHC contributed expertise and insight to the *Housatonic* project. Dr. William Dudley, Director, took a personal interest in the work and contributed as both a scholar and an administrator; Commander James Carleton, Deputy Director, tracked the project and assisted in many small but vital ways; Dr. Michael Crawford and the staff of the Early History Branch assisted with initial historical research; John Riley assisted with information from the Ship's History Branch archives. James Hunter of the Underwater Archaeology Branch produced extraordinary drawings of artifacts (Chapter 6). Finally, Donna Smilardo did an

remarkable job cutting red tape and handling the complicated financial aspects of the project.

Conservation of *Housatonic* artifacts was performed by Claire Peachey, Shea McLean, Jenifer Johnson, Jannicke Langfeldt, Maret Warner and Suzanne Davis of the Underwater Archaeology Branch, NHC.

The Superintendent of Fort Sumter National Monument, John Tucker, along with Chief Ranger Fran Norton, Interpretive Specialist Dawn Davis and Park Historian Rick Hatcher provided enthusiasm and input for the final report.

The *Housatonic* fieldwork revived existing partnerships that were responsible for success of the 1996 *Hunley* Assessment and produced similar results in 1999.

Personnel from the South Carolina Department of Natural Resources (SCDNR), Marine Resources Division, were again key players in offshore operations during the *Housatonic* Assessment and took an active interest in all aspects of the research—their professionalism nor their contribution to the project cannot be overstated. SCDNR Deputy Director John Miglarese went above and beyond to make the work viable. Robert Boyles assisted with project needs in Miglarese's absence. Director of Vessel Operations Randy Beatty redirected boats and captains to the project to ensure continuous operations for more than six weeks. Captains Paul Tucker and Mike Schwarz shared their knowledge and ensured safe operations onboard RV *Anita*. Artificial reef specialist Mel Bell and Biologists Doug Mellichamp and Bob Martore reviewed diving plans, assisted with fieldwork and analyzed recovered biological samples. Darryl Stubbs trained project personnel in CPR and first aid prior to the initiation of the project. Foster Folsom and Vernon Knox made their workshop available for project related repairs. Andy Jennings and Bill Anderson loaned the team the

17' Boston Whaler *Shorebird* and made it possible to investigate the Fourth Anomaly.

Tom Posey and Steve Yonce from South Carolina Educational Television displayed skill and good humor while they documented daily operations during work offshore in all conditions.

Volunteer archeologist, amateur researcher and nineteenth-century submarine enthusiast Michael Crisafulli's *Hunley* website (<http://home.att.net/~karen.crisafulli/nautilus.html>) suggested a link between Jules Verne and *Hunley* that was further indicated by Verne's short story *The Blockade Runners*. The *Hunley* internet discussion list (<http://groups.yahoo.com/group/csshunley/>) promoted a number of thoughts that were developed in this publication.

NPS-SRC contributed both personnel and considerable expertise to the *Housatonic* project. Larry Murphy, Dan Lenihan and Matt Russell reviewed the research design prior to initiation of fieldwork, assisted with technical questions from the field, and were instrumental in reviewing and improving the report that follows. Tim Smith assisted with GIS issues

and georectified the *Ossipee's* ship plans that was crucial for analysis. Frank Pais also contributed. Fran Day corrected and revised the manuscript, and she designed and produced the final publication.

Daisy Bailey volunteered her time to proofread the report.

Finally South Carolina Senator Glen McConnell and Chairman of the Friends of the *Hunley* Warren Lasch deserve special recognition and thanks. Senator McConnell provided state governmental support to the project and tracked developments closely. Warren Lasch supported the project both as chair of the Friends of the *Hunley* and personally, out of pocket, when finances were stretched thin.

Ultimately, the *Housatonic* Assessment created success from the earlier success of the 1996 *Hunley* Assessment and drew on a vast body of talent from multiple individuals, agencies and organizations. While a relatively small-scale project, it sowed the seeds for the much larger and spectacularly successful recovery of *H.L. Hunley* the following year by many of the same people and agencies.

EXECUTIVE SUMMARY

In May, June and July 1999, archeologists from the Naval Historical Center, National Park Service and South Carolina Institute of Archaeology and Anthropology systematically probed and documented the wreck of the Union blockade ship USS *Housatonic* located outside of Charleston Harbor, South Carolina. *Housatonic* was attacked and sunk by the Confederate submarine *H.L. Hunley* on February 17, 1864. Magnetic anomalies detected during the 1996 assessment of *H.L.*

Hunley were also documented and geological data pertaining to sediment deposition, age and structure were collected. The project documented damage to the Union ship that is probably the result of the Confederate attack and determined that sufficient articulated structure and preserved artifacts remain to make the *H.L. Hunley/US*S *Housatonic* Naval Engagement Site eligible for nomination to the National Register of Historic Places.

FOREWORD

The wrecks of Union warship USS *Housatonic* and Confederate submarine *H.L. Hunley* provide archeologists with an extraordinary opportunity to interpret a unique and historic sea battle. It is seldom that both victor and vanquished from such a battle end up on the seabed. What was a loss for both Union and Confederates in 1864 is today a gain for scientists, historians and the public in understanding this historic event.

In the spring and summer of 1999, archeologists from the US Navy's Naval Historical Center (NHC), National Park Service's Submerged Resources Center (NPS-SRC) and South Carolina Institute of Archaeology and Anthropology (SCIAA) began an investigation of the wreck of the steam screw sloop USS *Housatonic*. This research followed the 1995 discovery of *H.L. Hunley* by Clive Cussler's National Underwater Marine Association (NUMA), and complemented the 1996 survey and verification of the submarine by the same group of federal and state agencies that in 2000 would raise the submarine from the seabed. The 1999 *Housatonic* survey was part of an examination of the *Hunley-Housatonic* Naval Engagement Site as a whole, and was an important precursor to the later work on *Hunley*: the 2000 recovery of the submarine, the 2001 excavation of its main compartment and the 2002 forensic analysis and identification of its eight-man crew. Information and experience obtained during the *Housatonic* survey aided in planning for the 2000 recovery of *Hunley* and indicated the high level of preservation of both iron and fragile organic artifacts in the muddy marine environment.

Housatonic is a unique archeological example of a Union blockade ship. *Housatonic's* buried remains contain a wealth of information

about ship construction, life on the blockade and the arming and manning of a Union sloop-of-war during the Civil War. Even without the *Hunley* wreck as an associated site, *Housatonic* is a significant archeological site that would qualify for listing on the National Register of Historic Places. Although there are no immediate plans for continuing archeological investigations of the wreck site, the potential exists for future generations.

Ongoing research into both *Housatonic* and *Hunley* continues to shed new light on the attack and sinking of *Housatonic*. In particular, written accounts by *Housatonic's* crew continue to surface. These accounts aid in determining specifics of the sinking, and portray the impact of the loss on the ship's crew. For example, one account indicates that the starboard magazine was not set off by the torpedo's explosion, as once theorized, while another informs us that *Housatonic's* crew was lucky if they survived with the clothes on their backs. The fast attack and sudden sinking left the officers and sailors with no chance to rescue their personal effects. *Hunley*, on the other hand, survived the initial attack at least long enough to signal Confederate sentries ashore, as reported in both Confederate and Union accounts.

The archeological research conducted on *Housatonic* and continuing with *Hunley* epitomizes the significant contributions that professional archeology can bring to shipwreck sites dating to our recent nineteenth-century history. Detailed construction plans do not exist for either *Housatonic* or *Hunley*. In the case of both wrecks, the archeological evidence provides primary information not available in historic documents, and at the same time encourages closer examination of those archival documents that do exist. For example, the shoes

and other personal effects found on the *Housatonic* site vividly correspond to the officers' accounts of the quickness of the ship's sinking and the loss by the crew of all their possessions. At the same time, the discovery of the remains of eight crewmen inside *Hunley* goes against the initial expectations that the submarine carried nine men, as was reported by former *Hunley* crewman William Alexander. Archeological work on the *Housatonic* site has indicated the extent of destruction caused by *Hunley*'s torpedo. The ongoing excavation and analysis of *Hunley* is expected to reveal the cause of that vessel's mysterious loss. As research continues, a more precise picture of the events of February 17, 1864—and their consequences—will be formulated.

The 1999 fieldwork on the *Housatonic* site provided other benefits in addition to the archeological and environmental data that were products of the survey. The project was also a training ground for the archeologists who would later spend three long months diving on *Hunley* in near-zero visibility and strong currents. The diving and excavation conditions on *Housatonic* were often more strenuous and difficult than on *Hunley*. *Housatonic* provided some exceptional challenges. It was a large site to survey and interpret in zero visibility, being over 200 ft. long, close to 50 ft. at its maximum width, and completely buried under 5–7 ft. of sediment. Its iron remains created a strong magnetic field that cloaked key areas such as the engines, propeller and shaft. That the archeologists were able to locate features on the wreck, identify specific areas of the ship, and determine the orientation of the ship was quite a feat and a tribute to the skill of those involved.

This report is the result of the unique and successful partnership that was achieved between federal and state agencies: NPS-SRC, SCIAA and NHC. The partnership began with the 1996 *Hunley* survey, made the *Housatonic*

survey a success and accomplished the safe and unprecedented archeological recovery of *Hunley*. We would not be where we are today in our research into *Housatonic* or *Hunley* without this partnership.

This report also illustrates that professional underwater archeology is dependent upon a number of other scientific disciplines. The research designs of both the 1996 *Hunley* assessment and the 1999 *Housatonic* assessment incorporated geologists, engineers, chemists, microbiologists, marine biologists and others whose contributions have been invaluable. Scientific collaboration between practitioners from diverse fields opens new areas of research and adds depth to the interpretation of these shipwrecks. Such cross-disciplinary collaborations will continue to enrich and advance the field of underwater archaeology.

In writing the bulk of the USS *Housatonic* Site Assessment, Dr. David Conlin has done an excellent job of researching the ship, describing the field operations and analyzing the remains. Dr. Conlin's work in partnership with Dana Weise and Nancy T. DeWitt clearly explains the geology of the area and the site formation processes affecting both the *Housatonic* and *Hunley* wrecks. The description and preliminary analysis of the artifacts by Claire Peachey and Shea McLean helps to place the finds in a broader context, and the inclusion of their chapter on artifact conservation is an example of what should be the norm in archeological publishing. The commitment of NPS-SRC to the excellent production of this publication is commendable. The result is an insightful and readable contribution to the annals of professional underwater archeology.

Robert Neyland
Naval Historical Center

FOREWORD

The discovery of a site believed to be *H.L. Hunley* in 1995 by the National Underwater Marine Agency (NUMA) initiated a sequence of events that culminated in a successful cooperative federal, state and corporate project to recover the vessel. Along the way from discovery to recovery, archeologists from several agencies conducted field research projects to ascertain the nature of the remains and archeological context of this important site. Among these research projects was the examination of the remains of USS *Housatonic*, which *Hunley* sank just prior to becoming a historical mystery whose location was unknown for 131 years. Location of *Housatonic*'s remains has never been a mystery; it was marked as a navigation hazard and positioned on local charts.

Although, NUMA had conducted a brief survey of *Housatonic*, the project reported here was a more extensive archeological examination of the wreck. Though each vessel could have been reasonably examined as separate sites, this report has taken the much more productive and interesting approach of seeing both vessels (and the proximal "third" and "fourth" anomalies) as comprising a "naval engagement site." Immediately placing the research in a wider context and developing a specific research design (Chapter 3) to guide fieldwork proved especially fruitful and exemplifies a progressive, science-based approach to shipwreck archeology.

The focused, interdisciplinary research design laid out several goals and objectives to address in a single field session of about five weeks. The first goal was to augment what was known about the *Hunley/Housatonic* engagement in an archeological and historical context that would enhance knowledge about the battle appropriate for public interpretation.

Specific objectives were to characterize the *Housatonic* site and identify features that reflected its preservation and integrity, which is crucial to any future site management decisions. Beyond determining integrity, the researchers tasked themselves with investigating spatial organization, and, ambitiously, documenting battle damage from *Hunley*'s attack. Some involved in the early planning sessions were vocal skeptics. Predisturbance remote sensing indicated sediments completely covered *Housatonic*. They were doubtful that much remained of the structure, and in any case, determining *Housatonic*'s integrity was not feasible with time and resources available because it would require extensive, if not full, excavation. As for the project contributing to knowledge gained from the historical records—that was out of the question. This latter contention reflects an all-too-common pronouncement that archeological study of well-documented nineteenth century ships for which plans exist is really not particularly worthwhile.

Additional research objectives focused on site formation processes, whose delineation has become an increasingly important and productive emphasis for shipwreck archeology in the last decade. To begin to understand the site condition as it results from the naval engagement, the team had to fully explain and control for natural processes that had impacted the site. In particular, they had to separate postdepositional salvage activities from battle damage and account for the natural processes that have affected *Housatonic* in a manner similar to those documented during the 1996 *Hunley* investigation. For example, additional information about burial processes affecting stability and geotechnical analyses of sediments were essential for planning the *Hunley* recovery,

but these same data had bearing on the settling and burial of other elements of the engagement site. Site investigators took on an additional challenge—they planned to conduct field operations using minimum impact techniques so as not to contribute to site deterioration.

Chapter 4 presents the multistage strategy and the deceptively simple techniques deployed during minimally intrusive field operations. Something the chapter does not discuss about field operations are environmental variables that seriously impede fieldwork in the project area. Swift current, heavy offshore wave activity and mostly zero visibility conditions are common to Charleston Harbor. The site conditions did not impair probing operations, test excavations or documentation of hull diagnostic features and the outlying anomalies as presented in Chapter 5.

Analysis of the artifact assemblage recovered from the two small test excavations in Chapter 6 provides identification, functional categories and historical context key to site interpretation. Chapter 7's discussion and its inclusion as a chapter reflect the central importance of artifact conservation in this project. Frequently, discussion of artifact conservation appears as a report appendix, if it appears at all.

The comprehensive, interdisciplinary environmental context presentation (Chapter 8) fully meets and exceeds the research design objectives. The wide-ranging discussion sweeps from Pleistocene marl deposition to the 1989 hurricane Hugo and from the Continental shelf to local sediment diversion and increased site burial from jetty construction at both regional and site level. This wholly appropriate discussion includes micro and macro-scale processes informed by prior research in several disciplines. Remote sensing and analysis of cores and scour effects combine to provide a site-specific clarification of settling and burial processes, both current and past. This discussion provides a fine example of just how important site formation process explication is to credible

archeological inference regardless of whether one is considering a feature or the entire site, a test trench or full excavation.

Chapter 9, the report's core, provides an illuminating synthesis. Available information, archeological and historical, is woven together to present a compelling view of the engagement within its wider context. Richard Gould has advocated that underwater archeology become a historical science in which both historical particularist and social-scientific generalist approaches combine to provide credible interpretations of the maritime past. The synthesis presented in Chapter 9 does precisely that. Conlin incorporates results of systematic archeological fieldwork with a scientific explanation of site formation processes to develop a perceptive chain of inference that, when combined with an analytical read of historical records, provides a comprehensive explanation of the site. His explanation gives us a view of the historical reality of the events not available from other sources. Based on scant but sufficient evidence obtained from three small test trenches, vessel orientation, hull structure and internal arrangement, and activity areas materialize. Through this discourse, we learn that *Hunley's* successful attack on *Housatonic*, contrary to popular perceptions emphasizing differences between the industrial north and agrarian south that would have us believe this was a blacksmith weapon wielded in a serendipitous manner, was rather a sophisticated vessel whose commander incorporated past experience and military intelligence to inflict the maximum damage to a well armed, well prepared adversary. Conlin's broad interpretive context includes prior and contemporary events and generalizes about the use of surprise and initiative by those facing superior forces whether during the Civil War, WWI or more recently by the Naval Special Operations forces.

A final strength of this report is that not only does it represent a strong example of interdisciplinary underwater archeology that

provides a unique and credible view of the past; it exemplifies the public benefit that accrues from cooperation among federal and state agencies and private entities.

When Lieutenant George Dixon and his crew rammed an explosive charge into the side of USS *Housatonic*, it was but an instant and an intersection in a broad web of historical processes, sociopolitical designs and environmental variables that preceded and followed the night of February 17, 1864.

Though no history or archeological report can hope to completely encompass the full richness of the past, the report that follows gives a glimpse of how intimately interwoven these variables are and reflects a past just as complex and multifaceted as the present.

Larry E. Murphy
Chief, Submerged Resources Center

The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that every entry, no matter how small, should be recorded to ensure the integrity of the financial statements. This includes not only sales and purchases but also expenses, income, and transfers between accounts.

The second part of the document provides a detailed breakdown of the accounting cycle. It outlines the ten steps involved in the process, from identifying the accounting entity to preparing financial statements. Each step is explained in detail, with examples provided to illustrate the concepts.

The third part of the document discusses the various types of accounts used in accounting. It distinguishes between assets, liabilities, equity, revenue, and expense accounts, and explains how they are classified and balanced. It also covers the concept of debits and credits, which are essential for recording transactions.

The fourth part of the document discusses the importance of internal controls in accounting. It explains how internal controls help to prevent errors and fraud, and ensure that the financial statements are accurate and reliable. It provides examples of internal controls that can be implemented in a business.

The fifth part of the document discusses the role of the accountant in a business. It explains how accountants provide valuable information to management, and how they help to make informed decisions. It also discusses the ethical responsibilities of accountants, and the importance of maintaining objectivity and integrity.

CHAPTER 1

Introduction

David L. Conlin

At about 6:00 p.m. on the night of February 17, 1864, the tiny Confederate submarine *H.L. Hunley* slipped from its dock at Breach Inlet on the outskirts of Charleston, South Carolina, and began its historic voyage to attack the Union blockade. Almost three hours later, under a bright moon and in calm seas, the submarine and its crew of eight slammed a 135-pound black powder torpedo into the side of the Union blockade ship *USS Housatonic*. Backing away, *Hunley* tripped a lanyard and detonated the charge. As pieces of *Housatonic*'s decking blew high into the night sky, *Hunley* disappeared and remained lost for 131 years. The world's first successful submarine attack had been precisely planned and successfully executed by the Confederate States of America.

Even before Fort Sumter's fall in April 1861, the antagonists of the bloodiest conflict in American history had begun to examine their strategic options on both land and sea. For the North, the choice was relatively clear: drawing on hard-won experiences from both the Revolutionary War and the War of 1812, they followed the British Royal

Navy strategy of blockading enemy ports. Implementation of a blockade demanded a massive commitment of ships, logistical support and public finance that only the Union could make. For every ship on the blockade line, another was in port coaling, making repairs or resting its crew. The outright and hidden costs of maintaining an effective blockade could only be borne by the North—and both sides knew it.

The American Civil War was, with the possible exception of the Crimean War, the first conflict in which both sides reaped the dubious benefits of the Industrial Revolution. The telegraph, rifled guns, steam power, armor plate, the Gatling gun and a host of other newly developed efficiencies in communication, defense and killing all figured prominently in the conflict. Ultimately, General Winfield Scott's "Anaconda Plan," as the Union blockade and its associated land strategy came to be known, derived its effectiveness from the technological intensity of the war. As the paraphernalia of warfare grew increasingly sophisticated, its production became more difficult

in the absence of specialized industrial technologies. Consequently, imports like rifled guns and marine power plants from industrialized countries such as Great Britain assumed a disproportionate importance in the conflict for both contestants, but especially for the South. Denial of these strategically vital supplies through blockade, while not immediately catastrophic for the South, exacerbated the long-term effects of Northern strategic moves and helps explain the rapidity of the Confederate collapse in 1865.

Faced with the North's overwhelming industrial capacity, the South sought an advantage through application of tactical and technological ingenuity. In the naval conflict, this took both offensive and defensive forms. Offensively, unable to build a fleet to match the Union, the Confederacy focused its efforts on the construction of fast, well-armed, technologically sophisticated commerce raiders such as *CSS Alabama*, *CSS Texas* and *CSS Florida*. Defensively, the South's principal concerns were defending its ports and breaking the blockade. For harbor defense, the Confederacy turned to the relatively cheap but effective use of torpedoes (mines) and the construction of ironclads such as *CSS Virginia* and *CSS Palmetto State*. To break the blockade, the South had a small but vigorous program of innovative new technologies used for offensive operations—notably the semisubmersible and submersible. As the stranglehold of the Northern blockade increased over the course of the conflict, a parallel increase in inventiveness, creativity and risk-taking by the Confederacy attempted to match (and defeat) Union naval operations.

Concurrent with efforts to break the blockade came attempts to circumvent it. As it became apparent to all involved that the conflict would span years and not months, blockade running and the ships used became increasingly sophisticated. As Bradley (1974:30) observed:

When it began to be realized that the war would last years, and how greatly the

Southern Confederacy was dependent upon foreign imports, many British firms, and, also, a number of Southern merchants, made preparations for blockade running as a regular business and on a large scale. It required considerable capital to do this, for it was clear that blockade runners must not only be increased in numbers, but must be improved in type. The day of sailing vessels and ordinary steamers was over; steamers of great speed built expressly for the service were needed.

Conceptually, the blockade fell into three general phases. The early stages of the blockade were marked by relative ineptitude on the part of both the Union and the Confederacy as ships of all sorts ran in and out of Southern ports. During this phase, ships ran with impunity a blockade that existed more as a policy than as a reality. As Bradley observed, in the phase that followed, both sides recognized that the Civil War would last for more than a few months, and a conflict with no discernible end justified an investment in ships by both sides built expressly for running or enforcing the blockade. In the final phase, as Northern production capacity began to outstrip the South's, and the blockading squadrons grew in size and effectiveness, the South, no longer able to circumvent the blockade, was forced to try and break it. In this third phase of the blockade, the South developed some of the most advanced, risky, yet effective weapons of the entire Civil War. It is during this final chapter of the conflict that both *CSS David* and *H.L. Hunley* were finally deployed in action against the Union fleet off Charleston.

Structurally, the blockade was a curiously defensive offense, for once established by the stronger Union Navy, the two key tactical advantages of surprise and initiative were ceded to the weaker Confederate forces (Corbett 1911:183). Faced with the paradox of having initiative and surprise, but not able to defeat the

blockade head on, the South created weapons capable of avoiding a direct confrontation while still dealing a lethal blow to the more powerful Northern fleet—*H.L. Hunley* was, arguably, the most sophisticated of these weapons.

Submarine warfare during the Civil War emerged largely as a Confederate response to the Union blockade of Southern ports. Within the narrowly constrained and structured context of the blockade emerged a remarkable drama of actions and reactions, strokes and counterstrokes, and technological innovations and responses that culminated dramatically in naval combat off Charleston, South Carolina, in early winter, 1864.

The port of Charleston was an important economic nexus for the South at the outset of hostilities in 1861, but it became critical in 1862 following the fall of New Orleans to Union Admiral David Farragut and the loss of almost all Confederate Atlantic ports except Wilmington, North Carolina. Just 560 miles from the neutral port of Nassau, Bahamas—48 hours by fast blockade runner—Charleston became the South's primary artery for incoming foreign war materiel and its primary vein for outgoing cotton that provided hard currency for the cash-poor Confederacy (Bradlee 1974:30). Coupled with the port's strategic significance was the fact that Charleston in general, and Fort Sumter in particular, as the point at which the conflict began, had a symbolic importance to the people of America at least equal to that of the Southern capital Richmond, Virginia, and the Northern capital Washington, DC. That this port was fought for so savagely and yet so skillfully, should come as no surprise.

Ultimately, *Hunley's* attack on *Housatonic* demonstrated the tactical feasibility of submarine warfare. The reason for the 50-year time lag between this first successful attack and the development of full-scale undersea warfare should be seen as a combination of the inherent risk of technology far in advance of the current day, and a lack of vision on the part of military planners

following the Civil War who were not pushed to desperate risk-taking by overwhelming military exigencies. In 1896, the former assistant engineer of the Union Navy, Frank Marion Bennett wrote of the October 1863 attack by semisubmersible *CSS David* on *USS New Ironsides*:

This disaster was due to the excellence in the use of torpedoes which had been arrived at by the Confederates, they, in the absence of ships to carry on naval operations, being forced to wage war with these weapons both novel and unusual. The use of torpedoes was by no means a new thing, but it was a practice rather abhorrent to the minds of trained fighting men, and owed its development by the naval officers of the South to necessity rather than desire [Bennett 1896:424].

Indeed, innovation in technology, tactics and ethics is a hallmark of people attempting to maximize their resistance in the face of apparently overwhelming odds. Bennett's comment bears a striking resemblance to that of the German chief of Naval staff, Admiral von Pohl who, in a memorandum authorizing the unrestricted U-boat campaign that almost brought Great Britain to its knees during World War I, wrote: "The gravity of the situation demands that we should free ourselves from all scruples which certainly no longer have any justification" (Tarrant 1989:13).

The characteristic response of innovation to take advantage of initiative and surprise in the face of overwhelming naval superiority has numerous historical examples beyond the Civil War. German attempts to bring about a naval victory against a more powerful surface fleet by using a combination of submarines and commerce raiders during both the First and Second World Wars are the easiest parallels to draw to the first steps taken in that direction by the South, but others exist. The Russo-Japanese war of 1904–1905 in general, and events

occurring around the Russian port of Port Arthur in particular, mimic key events in Charleston four decades earlier. In World War II, Japanese plans to use midget submarines for the defense of Kiska Harbor during the Aleutian campaign and the deployment of *kaiten* suicide submarines in the face of a *de facto* American blockade of the home islands during the war's closing months echo the moves ordered by General Beauregard in 1864. In 1981–1984, the “Tanker War” in the Persian Gulf saw a similar use of mines and small boats in almost suicidal attacks by Iran in the face of American naval superiority. In short, *Hunley's* attack against *Housatonic*, though generally unappreciated, presaged the structure and responses of dozens of subsequent naval conflicts between navies of unequal strength. In these cases and others, a weaker foe can mount a spirited and effective counter to naval superiority using tactics, technology and an assumption of increased risk.

Hunley's historic attack confirmed the tactical effectiveness of the submarine as a weapon, but what was unknown at the time was that the economies of underwater warfare were similarly established. On February 17, 1864, a 40 ft. (12.1 m) submarine crewed by eight men sank a 207 ft. (63 m) sloop-of-war with a crew of 200, but the submarine and its crew were also lost. During World War II, American submarines in the Pacific had similar successes; foremost of which was the largest warship ever sunk: the 72,000-ton aircraft carrier *Shinano* with a crew of almost 4,000 torpedoed by the 1,500-ton submarine USS *Archer-Fish* with a crew of 83 in October 1944 (Enright and Ryan 1987). In fact, though comprising less than 1.6 percent of American naval strength, submarines caused more than half of Japan's total naval losses. The cost, however, was high; one out of every seven submariners in the Pacific died, and the submarine service had the highest casualty rate of any branch of the US armed service, including the Marines (Lowder and Scott 1980:217). In the Atlantic, the German U-boat

campaign from 1939 to 1945 sank 2,828 ships for a total of 14.6 million tons, but with a casualty rate of 85 percent—higher than that experienced by any other branch of the German service, including the Sixth Army, which was encircled and annihilated at Stalingrad (Terraine 1989:669).

“The combat of the *Merrimac* and the *Monitor*,” wrote former First Sea Lord Winston Churchill, “made the greatest change in sea-fighting since cannon fired by gunpowder had been mounted on ships” (Churchill 1995:398). Churchill, like most naval historians, saw the March 9, 1862, engagement between the Union ironclad USS *Monitor* and the Confederate ironclad ram CSS *Virginia* (*Merrimac*) in Hampton Roads as a critical moment in the development of modern naval technology and tactics. A British reporter who observed the Hampton Roads engagement wrote:

Whereas we had available for immediate purposes one hundred and forty-nine first-class warships, we have now two, those two being the [HMS] *Warrior* and her sister [HMS] *Black Prince*. There is not now a ship in the English navy apart from these two that it would not be madness to trust to an engagement with that little *Monitor* [*London Times*, April 4, 1862].

Though few would deny that the obsolescence of wooden ships of sail was vividly demonstrated in Virginia that day, many fail to appreciate that another profound development in naval warfare—the first successful attack on a surface ship by a submarine—occurred just two years later in the contested waters off the coast of Charleston, South Carolina.

The era of armored battleships peaked in the first half of the twentieth century, but by December 7, 1941, the punishment dealt to the American Pacific Fleet by Japanese naval air power at Pearl Harbor vividly demonstrated the looming strategic irrelevance of the ironclad legacy. In contrast to

battleships, though *Hunley's* success was not repeated for another 50 years, the implications of that first submarine attack continue to affect global geopolitics and strategic thinking today.

Hunley's attack was so far ahead of its time that it was science fiction, even after the fact. In Paris, a young writer who had already enjoyed commercial success in 1863 with his story *Cinq Semaines en Ballon* (*Five Weeks in a Balloon*), began writing what was to become his best known work, *Vingt Mille Lieues Sous les Mers* (*20,000 Leagues Under the Sea*) just one year after *Hunley's* attack on *Housatonic*. That author was, of course, Jules Verne.

Verne was fascinated with the technological developments and ragged dramas of the American Civil War, and he followed them closely. Events and technologies of the conflict figured prominently in many of his works, and his 1865 short story *Les Forceurs du Bloc* (*The Blockade Runners*) discussed in detail the mechanics of slipping into and out of Charleston with an enumeration of the channels leading into the harbor and their various merits. General Beauregard, commander of the Confederate garrison, was an important character in Verne's story. In fact, it is clear that Verne was well acquainted with Charleston during the Civil War, and in the pages of his most famous novel, *20,000 Leagues Under the Sea*, lie echoes of the conflict in general and *Hunley's* attack on *Housatonic* in particular. That an author who minted science fiction appears to have been drawn to the *Hunley* attack is a testament to the vision of those involved with the *H.L. Hunley*—James McClintock, Baxter Watson, Horace Lawson Hunley, Lieutenant George Dixon and the 21 other men who died as members of its three crews.

The USS *Housatonic* owes much of its fame to its unlucky distinction of being the first warship in history sunk by a submarine. This unfortunate happenstance, however, should not obscure the fact that the Union crew fought with skill and courage during 17 months of difficult duty off Charleston. During that time, *Housatonic*

captured blockade runners worth hundreds of thousands of dollars, provided sailors and marines for the heroic (though ill-fated) small boat attack on Fort Sumter, and defended the blockade fleet against the combined assault of two Confederate ironclads. Though not, properly speaking, one of the "Ninety Day Gunboats" that figured so prominently in Northern propaganda and the Union naval build-up during 1861–1862, *Housatonic* was the result of a rapid adoption and modification of an existing class of warships. In its design problems and successes lie the earliest physical traces of American industrial power turned to the mass-production of warships—a power that was to produce immense and war-winning naval fleets during both the First and Second World Wars.

Housatonic and *Hunley* represent two sides of a naval engagement that, fifty years later, would become a regular feature of war at sea—submarine against surface ship. Though the attack itself was a defining moment in naval history, it was only one point in a remarkable chain of events, intentions and coincidences that preceded and followed the losses of both vessels. Understanding the story of one side of the conflict illuminates the story of the other and ultimately allows a glimpse into how revolutionary it was to successfully plan and execute an attack by submarine in an era of steam and sail.

The Charleston blockade, though viewed differently from either side, produced common experiences of passion, boredom, terror and frustration for Americans from both North and South. These common experiences are reflected in deeds and stories of these deeds, as well as the material record documented through archeology. The documentary sources could only carry the story so far, and to peer deeper into the extraordinary events of February 17, 1864, demanded a perspective only archeology, working with history, could provide.

Hunley's attack on *Housatonic* produced an archeological site with two principal features, the wreck of *H.L. Hunley* and the wreck of USS

Housatonic, as well as a number of smaller but important components. For six extremely difficult weeks, a team of underwater archeologists from the Naval Historical Center, National Park Service and South Carolina Institute of Archaeology and Anthropology documented the wreck of *Housatonic* and associated outlying materials. This was both a continuation and a complement to earlier work done by the same three agencies on the wreck of *H.L. Hunley* in 1996 (Murphy 1998). What resulted was the archeology of a naval battlefield with both sides represented—directly comparable to similar archeological studies done at the Mexican-American War battlefield of Palo Alto

(Haecker 1994), the Civil War battlefield of Monroe's Crossroads (Scott and Hunt 1998) and the Indian War battlefield of Little Bighorn (Scott and Fox 1987).

This report is a companion to the archeology of *H.L. Hunley* (Murphy 1998), and it addresses the archeology of the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site. Though the principal focus is the wreck of USS *Housatonic*, readers should understand that, conceptually and operationally, *Hunley* and *Housatonic* have always been seen as two parts of a larger whole, a definitive moment in naval history that continues to affect us to the present day.

CHAPTER 2

USS *Housatonic* in Historical Context

David L. Conlin

PROLOGUE

With the election of Abraham Lincoln as the sixteenth President of the United States in November 1860 came a growing sense for many that profoundly divisive issues between North and South could no longer be resolved within the framework of a constitutional democracy. On December 20, 1860, South Carolina voted to secede from the Union, and shortly thereafter Mississippi, Florida, Alabama, Georgia, Louisiana and Texas followed suit. Six days later, with tensions skyrocketing, Union troops under the command of Major Robert Anderson removed themselves from Fort Moultrie, South Carolina, to the more defensible positions of Fort Sumter in the middle of Charleston Harbor. The Charleston *Mercury* called the move a “gross breach of faith” (Musicant 1995:80). Charleston militiamen moved into vacated Union positions at Fort Moultrie and began the *de facto* siege of Sumter—the opening moves of the Civil War had been made, and

Charleston’s reputation as the “Cradle of Secession” had been secured.

On January 9, 1861, the Union steamer *Star of the West* attempted to reinforce and resupply Anderson’s isolated garrison at Fort Sumter but turned back after being fired upon by Confederate forces. *Star of the West* returned to New York, its mission a failure (*Civil War Naval Chronology* [CWNC]:1-2). Three months later, on April 6, President Lincoln, in a move designed to force war or peace on the South, informed South Carolina Governor Francis W. Pickens that Sumter’s garrison would be resupplied (Musicant 1995:21). On April 10, fearing the consequences of a resupplied and strengthened garrison at Sumter, Southern General P. G. T. Beauregard was given orders to demand the evacuation of Anderson’s garrison and, if refused, “proceed in such a manner as you see fit to reduce it” (CWNC:1-6) (Figure 2.1).

At 4:30 A.M. on the morning of April 12, as a Union relief convoy composed of USS



Figure 2.1. Confederate Commander of Charleston, General P. G. T. Beauregard (courtesy National Archives).

Pawnee, *SS Baltic* and *SS Harriet Lane* stood off the Charleston bar waiting for daylight and the tide, mortar shells began to fall on the Sumter garrison; the following morning, hungry and exhausted, Anderson and his men surrendered (Porter 1985:25). The first shots of the Civil War had been fired. Charleston, the scene of opening hostilities, would become a primary strategic and propaganda objective for Union forces for the next four years.

OPENING MOVES

"We have no time, place, or means to build an effective navy. Our ports are, or soon will be, all blockaded. On land we do not fear Lincoln but what shall we do to cripple him at sea?"

Captain John A. Stevenson to Confederate Secretary of the Navy Mallory, May 21, 1861.

Six days after Fort Sumter's surrender, on April 19, 1861, President Lincoln declared a blockade of Southern ports from South Carolina to Texas. At that time, the Union Navy was totally inadequate to effectively blockade 189 harbors and more than 3,500 miles of American coastline (*CWNC* I-9, VI-30). At the onset of hostilities, the Union Navy had just 24 steam vessels in active service and five steam frigates that were out of commission (Canney 1990:91). Although additional vessels could be obtained by buying, chartering and modifying existing merchant ships, these stopgap measures could not produce the number of ships necessary for the long-term subjugation of Confederate naval forces on the open ocean nor to blockade their ports. Faced with the strategic necessity of closing Southern ports, the Union Navy embarked upon a crash shipbuilding program, and the so called "ninety-day gunboats"—relatively small gunboats for river and coastal defense—begin to emerge from Northern navy yards as early as September 1861 (Canney 1990:91). By the end of the war in 1865, the Union Navy had grown to a total of 670 ships, with 51,500 sailors and 6,700 officers (*CWNC* VI-30).

In June 1861, the keel of *USS Ossipee*, the first of a new class of screw sloops-of-war that would eventually include the *USS Juniata*, *USS Adirondack* and *USS Housatonic*, was laid down in the Portsmouth Navy Yard (Canney 1990:95). *Ossipee* was sponsored by Mrs. McFarland, wife of the editor of the *Concord Statesman* who would also sponsor the construction of the *USS Kearsarge*, the ship that was to sink the *CSS Alabama* in the same year of the *Hunley/Housatonic* engagement (*Dictionary of American Naval Fighting Ships [DANFS]*:609–610). *Ossipee* was a design adapted and modified for long-range, open-

ocean combat from the earlier *Mohican* class, which included *Kersarge* (Canney 1990:95). *Kersarge's* first captain, Charles W. Pickering, transferred to *Housatonic* in August 1863 and was in command when *Hunley* sunk *Housatonic* in 1864.

On August 16, 1861, President Lincoln issued a formal proclamation that declared the southern states to be in a state of insurrection and forbade all commerce with them. The proclamation said in part that: "...all goods and chattels, wares and merchandise coming from any of said [Southern] states ... by land or water, together with the vessel or vehicle conveying the same...shall be forfeited to the United States" (Official Records of the Union and Confederate Navies in the War of the Rebellion [ORN] ser. 1:6:90-91). The blockade was now

official, and Union naval forces moved to choke Southern shipping (Figure 2.2). Three months later, on November 7, Union forces, under Admiral Samuel F. DuPont, attacked and captured the key strategic anchorage of Port Royal, South Carolina (CWNC 1:31-34). This would become one of the most important anchorages of the war and the staging area for the crippling blockade of Charleston that soon followed (Figure 2.3).

Though the blockade existed as policy, and the gradual build-up of Union naval forces off the South Carolina coast was making it real, in the winter of 1861, the Union Navy was still unequipped to successfully enforce Lincoln's decree. Indeed, as late as fall 1862, a Union officer wrote to a colleague:



Figure 2.2. Union "Anaconda Plan" as characterized in 1861. Four years later, propaganda had been replaced by reality and the Confederacy's ability to prosecute the war was at a virtual standstill (courtesy National Archives).

I would be glad if I could only impress upon you some faint notion of how disgusting it is to us, after going through anxieties of riding out a black, rainy, windy night in three fathoms of water, with our senses on the alert for sound of paddles or sight of [a] miscreant violator of our blockade...when morning comes to behold him lying there placidly inside of Fort Sumter, as if his getting there was the most natural thing in the world [Musicant 1995:368].

Consequently, the Union turned to alternative means of closing Southern ports. Of these, the two "Stone Fleets" are perhaps the most well known and ultimately affected the fate of both *Hunley* and *Housatonic*.

The Stone Fleets were aging whalers, brought south from New England ports, loaded with granite from the farm walls of rural Massachusetts and Connecticut and sunk in the main channels of Southern ports to block shipping. The first Stone Fleet was intended for the mouth of the Savannah River, but, following capture of Fort Pulaski on Tybee Island by USS *Seneca* and USS *Pocahontas*, Southern forces sank their own Stone Fleet to prevent a Union upriver incursion (ORN ser. 1:12:325–326). On December 18–20, 1861, under the direction of DuPont's second in command, Captain C. H. Davis, the Union's first Stone Fleet of 16 ships was diverted to Charleston and sunk in the main shipping channel just off Morris Island (*DANFS* V:424). Southern General Robert E. Lee wrote in



Figure 2.3. South Carolina coast showing the Union base at Port Royal and Confederate port of Charleston. This 1861 map, published in Boston, allowed the northern public to track the unfolding drama of the Union blockade (courtesy National Archives).

outrage to Confederate Secretary of War J. P. Benjamin that: "This achievement, so unworthy any nation, is the abortive expression of the malice and revenge of a people which it wishes to perpetuate by rendering more memorable a day more hateful in their calendar" (ORN ser. 1:12:421-423). Southern ire notwithstanding, one month later, on January 26, 1862, 14 ships of the second Union Stone Fleet were sunk off Sullivan's Island between the shore and Rattlesnake shoals (ORN ser. 1:12:513). This left only the Swash Channel and a portion of Maffit's Channel navigable into Charleston Harbor. As the Stone Fleets began to block these navigation channels into Charleston, sedimentation patterns changed, the channels began to fill, and the ships slowly scoured themselves into the sandy bottom. The inshore side of Maffit's Channel and the Swash Channel, south of Rattlesnake Shoal (and the point of contact between *Housatonic* and *Hunley*) became the two primary routes for Southern vessels running the Union blockade. The Union Navy had narrowed and defined the field of conflict outside of Charleston (Figure 2.4) to two channels their few vessels could more easily control.

As the Union armed itself for the intensifying naval conflict, concurrent efforts were underway in the Confederacy. On March 12, 1862, in New Orleans, Confederate engineers Baxter Watson and James McClintock launched *Pioneer*, the first of three submarines that would culminate with *H.L. Hunley* (Ragan 1999:47).

HOUSATONIC

On November 20, 1861, the same day the Union's first Stone Fleet arrived at its Port Royal staging point, the second-rate, steam sloop-of-war USS *Housatonic* was launched from the Boston Navy Yard. As part of the rapid build-up of Union naval forces, *Housatonic*, like its

sister ship USS *Ossipee*, was designed for long-range, open-ocean cruises. These ships were intended to be the first line of defense against the increasingly serious depredations of Confederate raiders such as the CSS *Alabama* and CSS *Oreto* that were then engaged in a highly successful campaign of *guerre du course* (commerce raiding) against Union merchant shipping worldwide. Modified from the existing *Mohican* class of first-rate screw sloops, the *Ossipee* class was designed with increased beam and displacement (Canney 1990:95). As with *Ossipee*, the \$231,526.71 cost of *Housatonic* was partially offset by civilian sponsors; in this case, Jane Coffin Colby and Susan Paters Hudson (the daughter of the commandant of the Boston Navy Yard) (ZC Files, Navy Department Library; DANFS III:370-373).

Housatonic was built at 205 ft. (62.4 m) long with 38 ft. (11.6 m) at maximum beam and a 16 ft. 10 in. (5.1 m) depth for an overall displacement of 1,934 tons (Bennet 1896:Appendix B) (Figure 2.5). The hull was solid framed of live oak with 4½ x 5/8-in. (11.4 x 1.6 cm) iron cross-strapping at 3-ft. (.9 m) intervals throughout the hull. The hull was copper sheathed below the load line for protection against marine borers (*Boston Daily Advertiser*, November 21, 1861).

The *Ossipee* class was the first instance in which the entire power system of both engines and boilers were designed by the Union Navy's Chief Engineer Benjamin Isherwood (Canney 1990:95). Isherwood's design reflected his theories that smaller cylinders and larger boilers were required to produce greater power. As a consequence, the large, twin Martin Tubular Patent boilers were married to relatively small, horizontally opposed, direct-action cylinders 42 in. (1.06 m) in diameter with a 30-in. (.8 m) stroke (Figure 2.6) (Canney 1990:95). Isherwood's engine design proved problematic for the *Ossipee* class because the firms building

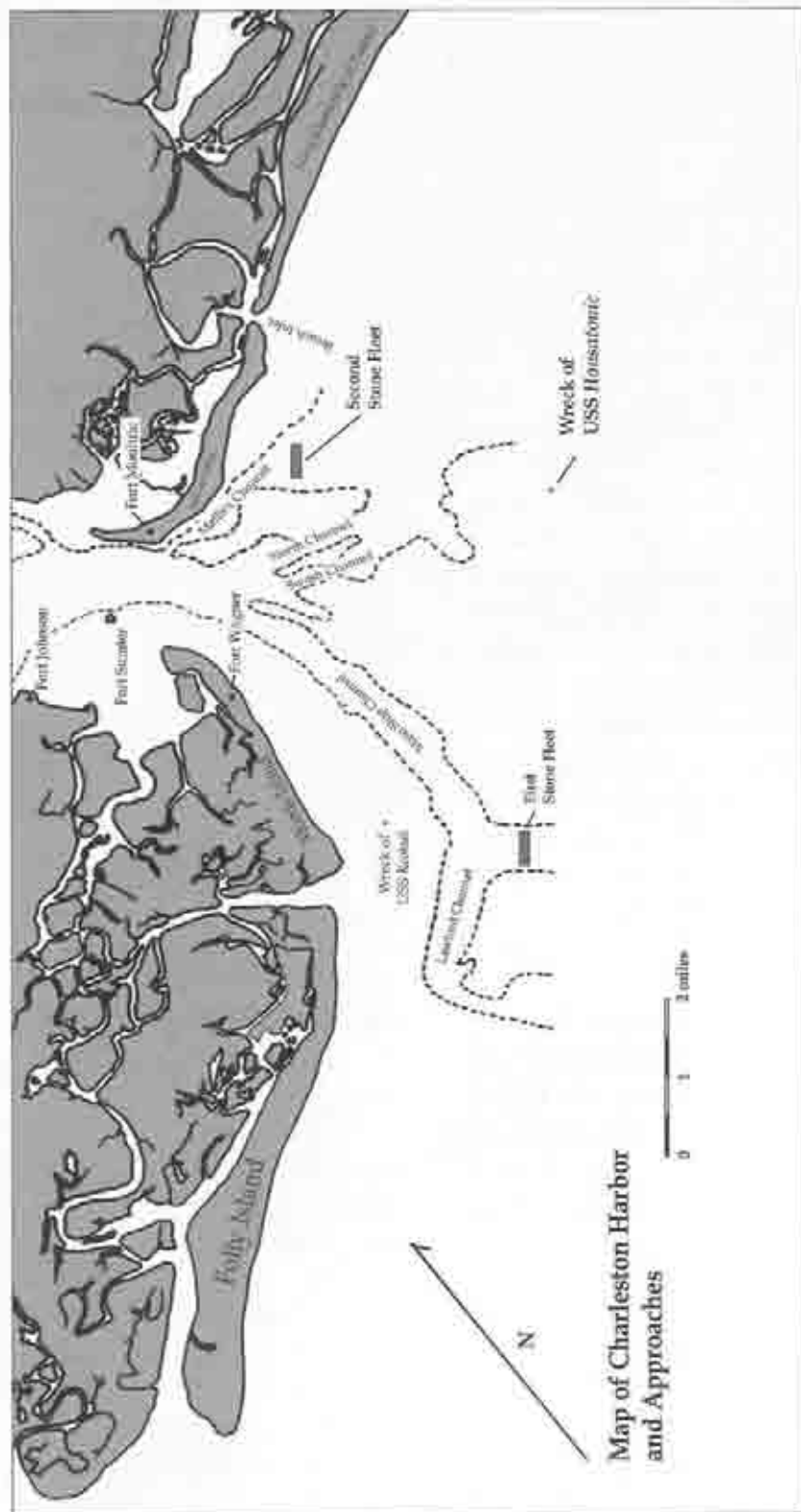


Figure 2.4. Map of Charleston Harbor and its approaches as it was during the blockade (after ORN ser. 1:14:3).



Figure 2.5. The only surviving image of USS *Housatonic* (courtesy Naval Historical Center (NHC)).

the engines had little or no experience in the production of marine power plants and were unfamiliar with the engineering tolerances required for the successful production of higher pressure steam machinery. Both *Housatonic's* sister ships, *Ossipee* and *Janiata*, experienced extensive engine problems early in their careers (Canney 1990:95). The Globe Iron Works of Boston constructed *Housatonic's* engines and boilers, which provided an estimated 1,150 horsepower and an anticipated speed of 14 knots (*Boston Daily Advertiser*, November 21, 1861). In addition to the steam power plant and 235 tons of coal, *Housatonic* carried three masts in a bark rig (Figure 2.7). Though classed as an auxiliary propeller, in reality, *Housatonic* relied primarily on steam as a source of propulsion. Crew complement for *Housatonic* was 200 sailors and officers with space for another 100 marines if necessary (Canney 1990:95) (Figure 2.8).

Housatonic was originally armed with one 100-pound and three 30-pound Parrot rifles, one XI-in. Dahlgren smooth-bore cannon, three 33-pound cannons, two 24-in. howitzers, one 12-in. howitzer (the howitzers were for the ship's boats) and one 12-in. rifle (Silverstone 1989:42). In April 1863, armament was increased by the addition of two 32-pound smooth-bores, and another two were added in November of that year (ZC Files, Navy Department Library).

Procurement problems for engines and armaments delayed the entry of *Housatonic* into active service for nine months. Finally, on August 29, 1862, USS *Housatonic* was formally commissioned as a second-rate screw sloop-of-war in the Union Navy, and on September 11, under the command of Captain William R. Taylor sailed with USS *Canandaigua* from Boston to Port Royal, South Carolina to participate in the Union blockade. On September 19, 1862, both ships arrived in South

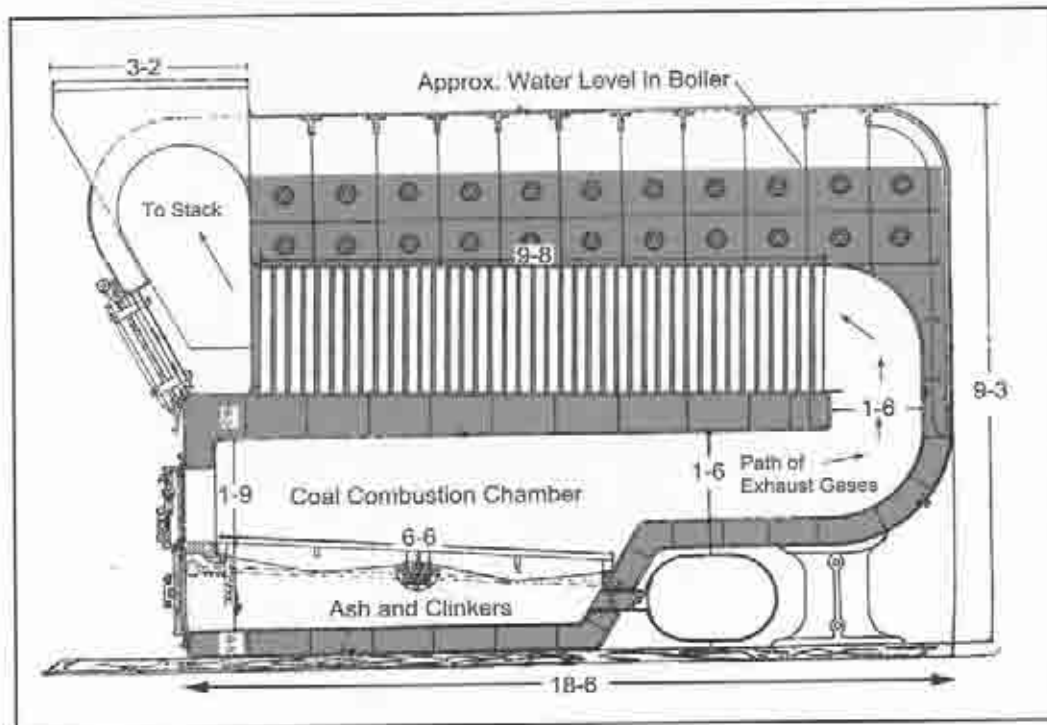


Figure 2.6. Martin vertical patent boiler. All measurements in ft.-in. (after Bennett 1896:222).



Figure 2.7. Rigging arrangements on *Housatonic*'s sister ship USS *Ossipee* in Hawaii, 1867. Despite early engine problems, the *Ossipee* design was fundamentally sound. Several of the class served for many decades after the war (courtesy NHC).



Figure 2.8. Muster of marines and sailors on the deck of an *Ossipee*-class sloop-of-war circa 1887–1888 (courtesy NHC).

Carolina and joined the front line of the blockade (*DANFS* 1991:371).

BLOCKADE

“Honor and glory shall be the watchword of the Navy and not profit.”

Admiral David Porter, October 31, 1864

Life on the Union blockade was a curious blend of ongoing boredom punctuated by brief instants of fierce excitement and occasional terror. After weeks or months of sitting on the blockade line, a chase for a Southern blockade runner or a Confederate naval attack would unleash pandemonium that might last only minutes or hours at the most. The excitement existed on both sides, and one Confederate blockade runner later wrote: “Nothing I have ever experienced can compare with it. Hunting, pig-sticking, steeple-chasing, big-game shooting, polo—I have done a little of each—

all have their thrilling moments, but none can approach ‘running a blockade’” (Taylor 1896). Incentive for Union vigilance was huge, and capturing a blockade runner provided tangible rewards for the sailors on federal ships as the prize value of the capture was distributed in shares among the crew, who were typically paid 12 to 18 dollars per month (Figure 2.9). A single, rich capture could provide an entire ship with the equivalent of months or even years of wages.

The constant blend of tension and boredom took its toll on the sailors of the Union Navy, while the need to maintain operational readiness extracted a similar toll on the ships and machinery of the blockading squadrons (Figure 2.10). On August 21, 1862, Admiral DuPont wrote to Assistant Secretary of the Navy Gustavus Fox that the fires of the USS *Pembina* had been out only 70 hours since the ship was commissioned 10 months earlier in October of 1861; other ships experienced similar wear

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Figure 2.9. Union Navy recruiting poster promising huge prizes for sailors. Some ships, including *Housatonic*, did extremely well under the program of prize awards for captured Confederate vessels (courtesy National Archives).

Figure 2.10. Union sailors on *USS Pawnee* off Charleston during the blockade (courtesy Library of Congress).



(ORN ser. 1: 13:268–269). Isolated at the end of an extended supply line that ran hundreds or thousands of miles to industrial centers in the North, admirals in charge of the Gulf, South Atlantic and North Atlantic Blockading Squadrons competed for new men, materials and ships. *Housatonic*, reporting to Port Royal, was originally slated to join Admiral David Farragut's Gulf blockading squadron in Mobile, Alabama (ORN ser. 1:19:154).

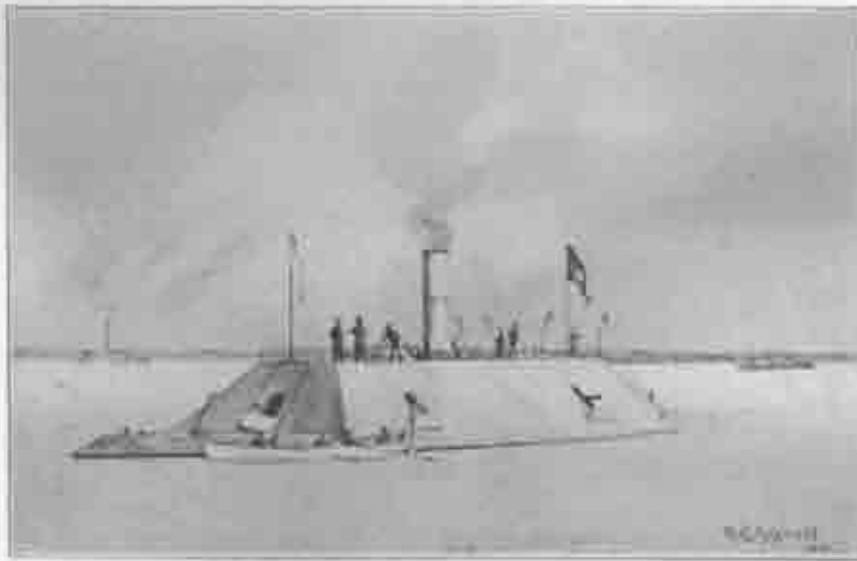
On December 12, 1862, Admiral DuPont ordered Captain Taylor to join the Union blockade fleet on station off Charleston (ORN ser. 1:13:478). The next month, on January 22, 1863, the newly arrived crew of *Housatonic* mistakenly fired on the gunboat USS *Ottawa* as it chased a Confederate schooner trying to run into Charleston harbor (ORN ser. 1:13:525–526). The following week, on January 29, *Housatonic* and the schooner *G.W. Blunt* successfully intercepted the Confederate blockade runner *Princess Royal*. While attempting to navigate into the harbor via the still-open channel along the shore of the Isle of Palms and Sullivan's Island, *Princess Royal* was driven ashore and captured (ORN ser. 1:13:551–552). The cargo of marine engines, medicine, armor, armament and associated machinery was the richest prize-capture of the entire Civil War and a significant setback to the program of Confederate ironclad construction. Altogether, \$337,816.11 was split five ways with *Housatonic* receiving a significant share (Porter 1985:841).

For three days the captured *Princess Royal* anchored next to *Housatonic*, which was acting as flagship for the blockade, while *Powhatan* and *Canandaigua* were coaling in Port Royal. Aware of the temporary weakness of the Union blockade, Confederate forces attempted to wrest back the prize from its Union captors. This attack turned into the single largest naval engagement in the Charleston blockade, and *Housatonic*, as the acting flagship, played a central role in the battle that followed (Bennett 1896:369).

Under the command of Flag Officer Duncan Ingraham, the two Confederate ironclad rams CSS *Palmetto State* and CSS *Chicora* burst out of Charleston harbor early on the morning of January 31, 1863 (ORN ser 1:13:589) (Figure 2.11). *Palmetto State*, Ingraham's flagship, bore down on the federal fleet and rammed into the starboard stern quarter of the anchored blockader USS *Mercadita*. As the two ships grappled together, *Palmetto State* opened fire with its 7-in. Brooke rifle and destroyed the portside boiler and condenser of *Mercadita*, crippling the blockader (Musicant 1995:379). As *Mercadita* slowly filled with water, *Palmetto State* asked for and received the surrender of the federal ship. Satisfied with the word of Captain Henry Stellwagen that the ship and crew were now Confederate prisoners, and unable to spare the crew for a boarding party, Ingraham steered *Palmetto State* towards the Union blockade ship *Quaker City* (Musicant 1995:379–80).

As *Palmetto State* attacked *Mercadita*, the Confederate ram CSS *Chicora* attacked and mauled the Union blockader USS *Keystone State*. Sneaking to within 50 yards, *Chicora* opened fire and smashed *Keystone State*'s port paddlewheel, condenser and boiler. Crippled and sinking, the Union vessel slowly moved to escape. Unaccountably, *Chicora* did not press home the attack, and *Keystone State* limped to safety behind the Union blockade line (Musicant 1995:380).

While the alarm from *Palmetto State* and *Chicora*'s attacks spread throughout the fleet, the captured prize *Princess Royal*, lying moored by *Housatonic*, got up steam from cold water, "... by the almost superhuman exertions of Mr. Thurston," and escaped out to sea (Bennett 1896:371). *Housatonic*, as the largest ship of war then on the blockade, was the first to respond. In a running fight with both ironclads, *Housatonic* chased the Confederate ships as they withdrew to the shelter of Fort Sumter's



C.S. IRONCLAD CHICORA

Figure 2.11. Confederate ironclad CSS *Chicora* which, along with the CSS *Palmetto State*, attacked and mauled the Union blockade in January 1863 (ORN ser. 1:13:577).

guns. After the battle, the following account of the engagement taken from *Housatonic's* log was dispatched to Secretary of the Navy Gideon Welles;

At 5:05 a.m. saw the flash and heard the report of a gun bearing S.W.; the firing continued about half an hour at intervals, when there was a cessation of about twenty minutes; it was then resumed, the direction varying from S.W. to S. Could not see the vessels from whence it came on account of the dense mist about the horizon. At 6:15 a. m. saw three vessels together, bearing S. by E.; made one of them out to be the *Quaker City*. USS *Augusta* burned Coston's signals, which were not understood, but which were supposed to mean danger; she got underway and

stood toward the firing. We immediately slipped and steamed after her, all hands at quarters. Hailed the prize steamer [*Princess Royal*] and ordered her to get underway. About 6:40 a.m. saw black smoke to the westward and as soon as it became light enough to see, discovered a ram with a Confederate flag, steaming rapidly toward Fort Sumter. The *Augusta* was then engaged with another vessel. Ran down between them, when a second ram was discovered, on which we opened fire at 7:08 a.m. She was then moving slowly toward the direction of the harbor. At 7:37 a. m. she went out of range. We fired thirty-four guns at her in this interval; she returned our fire, but none of her shots struck us. We knocked away her pilot house and forward

flagstaff. At 7:50 am, discovering her roof covered with men, fired two shots from the 100-pounder rifle at extreme elevation, both of which fell short. [ORN ser. 1:13:589].

Immediately after the attack, Admiral DuPont ordered the most powerful ship in his command, the USS *New Ironsides*, to move inshore at night and place itself between the Union fleet and possible future attacks (ORN ser. 1:13:623). This repositioning placed the vessel in harm's way the following October and, indirectly, contributed to the chain of events that would result in the loss of *Housatonic*.

Another military result of the Confederate attack was that DuPont's planned ironclad assault against Fort Sumter was delayed until his force of five ironclads could be augmented with additional reinforcements. Though wary of the chances for the coming attack, DuPont was reassured by Secretary Welles that any responsibility for failure would be shared by the Navy Department (Musicant 1995:338). This promise would be faithlessly broken in the aftermath of the disastrous Union attack later that spring (Figure 2.12).

As the military results of *Chicora* and *Palmetto State's* attack were being assessed, the Confederate defenders of Charleston moved to capitalize politically on the ironclad breakout. Three days later, on February 2, 1862, General Beauregard issued the following statement in the *Savannah Republican*:

The results of the engagement are two vessels sunk, four set on fire and the remainder driven away.

Yesterday afternoon General Beauregard placed a steamer at the disposal of the foreign consuls to see for themselves that no blockade existed. The French and Spanish consuls



Figure 2.12. Union Secretary of the Navy Gideon Welles, a key figure in the political maneuverings that accompanied the naval operations around Charleston (courtesy National Archives).

accepted the invitation. The British consul, with the commander of the British war steamer *Petrel*, had previously gone 5 miles beyond the usual anchorage of the blockaders and could see nothing of them with their glasses.

Late in the evening four blockaders reappeared, keeping far out.

This evening a large number of blockaders are in sight, but keeping steam up ready to run.

The foreign consuls here have had a meeting last night. They are

unanimously of opinion that the blockade of this port is legally raised [ORN ser. 1:13:617].

Union naval officers and politicians moved quickly to quell any idea that the blockade had been raised since, if true, it would require another act of Congress to reinstate the blockade legally, and this would entail a delay of up to three months and, more important, a reexamination of the Union's desires to pursue the entire conflict (Bennett 1896:373). In this short period of relief, the South could have received a vital infusion of war material and foreign currency.

The political maneuverings in the aftermath of the Confederate attack spoke to the heart of a fundamental weakness in the Union blockade that the Confederacy made every effort to exploit. Though the Lincoln government maintained that the Southern states were members of the Union in insurrection, the act of imposing a blockade required the enactment of political processes that both took time and implicitly recognized the Confederacy as a sovereign nation. The declaration of a blockade likewise affected other nations, primarily Britain and France who, in their moves to declare neutrality in the conflict, also implicitly recognized the Confederacy. This implicit status secured the South the right, under international law, to purchase arms in neutral countries, to secure loans to purchase war material, and to legally commission warships as privateers for open ocean raiding (McPherson 1988:387). Ultimately however, both Britain and France found reasons to live with the political ambiguity of implicit recognition of the South, not the least being that it allowed them to make money selling weapons to both the Union and the Confederacy. In end, the Confederate ironclad breakout was not decisive and, unwilling to raise the blockade on what amounted to a technicality, the Union fleet

maintained its position in the channels leading into Charleston.

Throughout late winter and early spring 1863, life on the Union blockade resumed its monotony. On the Confederate side, experiments continued with submarines. Following the loss of New Orleans to Admiral David Farragut's fleet in April 1862, Baxter Watson and James McClintock scuttled *Pioneer* and shifted operations to Mobile, Alabama. Construction of a second Confederate submarine, *Pioneer II*, began in July 1862, though difficulties in procuring an "electromagnetic engine" led to delays and eventual modification to human power. Finally in January 1863, *Pioneer II* was launched in Mobile. While under tow to attack Union blockading vessels outside Mobile Bay in February 1862, *Pioneer II* sank in a heavy chop (Ragan 1999:93, 97). Undaunted, Watson, McClintock and a third partner, Horace Lawson Hunley, embarked on construction of a third submarine drawing upon the lessons learned on the previous two. This third craft was launched in Mobile in July 1863 (Ragan 1995:28).

On April 7, 1863, the long-planned Union ironclad attack against Fort Sumter began. *Housatonic* played a supporting role, but was not directly involved in the attack. Under Admiral DuPont, nine Union ironclads steamed into Charleston Harbor to attack Fort Sumter with USS *Weehawken* in the front pushing an anti-torpedo raft (Porter 1985:374). As the outgoing tidal current surged through the mouth of Charleston harbor, the raft buckled and *Weehawken* lost way. When the other ironclads moved into the harbor, the currents grabbed them as well, and the attack degenerated into a dangerous series of misses and near groundings for the Union fleet. Maneuvering more to stay afloat and avoid collision than to attack, DuPont's ironclads were shot to pieces. USS *Keokuk* limped out of the harbor after being hit 90 times by the Confederate batteries. The

following day, despite the crew's efforts, *Keokuk* sank in the main channel, just off Morris Island (CWNC III-59) (Figure 2.13). His earlier promise notwithstanding, Secretary of the Navy Welles did not step up to cover Admiral DuPont from the rain of irate public opinion that descended upon him.

Unwilling to admit that the 'invincible' ironclads might have weaknesses, Union propagandists had no choice but to paint the attack as a command failure. While DuPont attended to the political fallout from the abortive attack, under Union naval guns and the cover of night, Confederate forces removed *Keokuk's* sunken XI-in. Dahlgren guns and, more important, its code book (CWNC III-138). One of the principals in the recovery of *Keokuk's* materials was Confederate Naval Officer William T. Glassell, who would later show similar nerve during his attack on the USS *New Ironsides* with the newly built semisubmersible CSS *David* (ONR ser. 1:14:78).

In the weeks that followed the failed Union attack, Confederate blockade running intensified with mixed results. On April 19, 1863, *Housatonic* captured the outbound blockade runner *Neptune* loaded with a cargo of cotton and turpentine. *Housatonic's* crew split prize money of \$14,204.24 with the crew of *New Ironsides* (ORN ser. 1:41:148-149; Porter 1985:840). One month later, on May 16, 1863, *Housatonic* assisted with the capture of the sloop *Rontereau* and received a 1/15 share of the \$1,351.71 prize. Confederate counterattacks notwithstanding, the increasing Union naval forces blockading Southern ports had a noticeable effect on the ability of the South to run the blockade. On June 11, for example, the blockade runner *Havelock* ran past the USS *Memphis*, *Stettin* and *Ottawa*, but was so severely damaged by Union gunfire that the crew ran the ship aground on Folly Island where it was later burned. Captain Turner, commanding officer of USS *New Ironsides* reported that the



Figure 2.13. USS *Keokuk*, the first of three ironclad casualties for the Union blockade of Charleston (ORN ser. 1:14:24).

ship was “a total wreck” (ORN ser. 1:14:253). By the end of the war, 687 blockade runners had been captured by Union naval forces for a total of more than 10 million dollars in prize money. As Musicant (1995:370) observes: “In 1861 one blockade runner in 10 was captured; in 1862, one in eight; in 1863–64, one in three; and in 1865, one in two. Such figures indicate that the Confederacy had reached the point of strangulation” (Figure 2.14).

While the Union stranglehold on Charleston tightened in 1863, offensive operations directed at capturing Fort Sumter and other harbor defenses moved slowly despite efforts to force a decisive victory. As spring turned to summer, the political aftermath of the first monitor attack

against Fort Sumter was finally played out. On July 6, 1863, unable to recover from the disastrous assault by Union ironclads in April, Rear Admiral DuPont was replaced by Rear Admiral John Dahlgren as commander of the South Atlantic Blockading Squadron (*CWNC* III-111) (Figure 2.15). That same month, Captain Taylor was relieved of duty as commander of *Housatonic* due to illness. By August 20, Charles W. Pickering had replaced him as captain. (ORN ser. 1:14:389) (Figure 2.16).

On July 10, under the command of newly appointed Admiral Dahlgren, Union ironclads *USS Catskill*, *Montauk*, *Nahant* and *Weehawken* began bombardment of Confederate forces on



Figure 2.14. Confederate blockade runner, possibly *Celt*, wrecked on the stone jetty of Sullivan’s Island. As the effectiveness of the Union blockade increased over the course of the war, this scene became more and more common (courtesy Library of Congress).

Figure 2.15. Admiral John Dahlgren on USS *Pawnee* off Charleston (courtesy Library of Congress).



Figure 2.16. *Housatonic's* second captain, Charles W. Pickering (courtesy South Carolina Archives).



Figure 2.17. Dahlgren (center) and his staff on USS *Pawnee* during the blockade of Charleston (courtesy National Archives).

Morris Island in support of a Union ground offensive (ORN ser. 1:14:316) (Figure 2.17). Under cover of the ironclad's guns, federal troops commanded by General Quincy Gillmore moved to attack Confederate positions surrounding Fort Wagner, a key fortification for the defense of Charleston Harbor, on the northern tip of Morris Island.

The mounting Union pressure on the Confederate defense of Charleston produced a predictable response from an increasingly desperate General Beauregard. As the key to Fort Sumter crumbled under the combined assault of Gillmore's troops and Dahlgren's ironclads, the fragility of Charleston's defense became a stark and unpleasant reality to the Confederacy. If Fort Wagner and Morris Island fell, then Sumter would fall, and if Sumter fell, so too would Charleston. On July 12, Beauregard wrote Captain Tucker, commander of Confederate Naval forces in Charleston:

The presence of the enemy's monitors within the bar eminently endangers our works on Morris Island, the holding of which is so vital to the defense ultimately of Fort Sumter. It has, therefore, become an urgent necessity to destroy, if possible, part or all of these ironclads and may not this be done with means at our disposition?

Beauregard declared that this would be: "... an event which I need not say would be of incalculable importance to the defense entrusted to us" (ORN ser. 1:14:725). The next week, Beauregard followed up with a second message to Tucker:

I believe it my duty to acquaint you with the fact that I consider it of the utmost importance to the defense of the works at the entrance of the harbor that some effort should be made to sink either the

Ironsides or one of the monitors now attacking the works on Morris Island, not only because of the diminution thus effected in the enemy's means of offense, but because of the great moral effect that would inevitably result from such an occurrence. The stake is manifestly a great one, worthy of no small risk... One monitor destroyed now will have greater moral and material effect, I believe, than two sunk at a later stage in our defense [ORN ser. 1:14:728].

In August 1863, a request by General Beauregard, the third Confederate submarine produced by Watson, McClintock and Hunley was moved to imperiled Charleston by rail from Mobile, Alabama. On August 12, 1863, while the Union siege of Fort Wagner was proceeding steadily, if not quickly, the submarine arrived and the crew began preparations for an attack against the Union blockade (Ragan 1995:35, 37).

While the Union paid out prize money for the capture of Confederate blockade runners to ordinary sailors, the Confederacy established an analogous practice for the destruction of Union naval vessels. On May 21, 1861, the Confederate government had guaranteed the right of patent for any invention beneficial to the war effort reserving for the government the right to use it and declaring that it would: "pay to any private armed vessel commissioned under said act 20 per centum on the value of each and every vessel of war belonging to the enemy that may be sunk or destroyed" (CWNC I-14). In Charleston, the newly arrived submarine crew were met with the same opportunities. Brigadier Jordan, Beauregard's chief of staff, was advised by Mr. B. A. Whitney that a reward of \$100,000 would be paid for the destruction of the Union ironclad *New Ironsides* and that: "... a similar sum for the

destruction of the wooden frigate *Wabash* [Dahlgren's flagship], and the sum of fifty thousand dollars for every monitor sunk" was also offered (CWNC III-128).

On August 23, 1863, under the command of Admiral Dahlgren, the Union monitors *Weehawken*, *Montauk*, *Nahant*, *Passaic* and *Patapsco* attacked Fort Sumter for the second time. As with the April attack, the Union ironclads were heavily damaged by Confederate guns. Sumter remained in Confederate hands, though with the combined land and sea assault on Fort Wagner, the Union was slowly gaining ground (Figure 2.18).

The following day, August 24, 1863, Union spies in Nassau reported the existence of a Confederate submarine in Charleston Harbor to Secretary of the Navy Gideon Welles. Welles passed a copy of the letter to DuPont. The following day, *Hunley's* civilian crew, thought too timid by the Confederate command, was replaced by a crew of Confederate sailors from the battle-tested ironclad rams *Chicora* and *Palmetto State*. Perhaps unfamiliar with the quirks of their new craft, five members of the new crew drowned after *H.L. Hunley* sank during training at Fort Johnson on August 29, 1863. The submarine would not be recovered until September 14 (Ragan 1995:42, 46, 58).

After two months of bloody siege and thousands of casualties, Fort Wagner, the Confederate stronghold on Morris Island was abandoned on September 7, 1863. One more step toward the defeat of Charleston was taken by the Union, and their thoughts now turned to the capture of Fort Sumter (Burton 1970:179).

Following the fall of Morris Island, Dahlgren sent a signal to the Confederate defenders of Fort Sumter demanding its surrender. Still defiant, the garrison replied: "Come and take it" (ORN ser. 1:14:567). Emboldened by their recent success and under the impression that Sumter was lightly held, both Admiral Dahlgren and General Gillmore



Figure 2.18. Officers and crew onboard the Union monitor USS *Catskill* on the Charleston blockade (courtesy Library of Congress).

independently planned a follow-up attack on the fort on the night of September 8–9, 1863. On the afternoon of the planned attack, each learned of the other's intentions. Unable to agree who should be in command, Gillmore withdrew his forces from the attack. Confederate forces, using the code book captured from the *Keokuk* in April, read all the signals passing between Gillmore and Dahlgren and learned of the attack (Burton 1970:195; CWNC III-140) (Figure 2.19). Late on the night of September 8, 400 Union sailors and marines, including 30 men from USS *Housatonic*, in a flotilla of small boats attempted to take Sumter by stealth, unaware of the Confederate reception prepared for them. The operation was a disaster of nighttime confusion, Confederate grapeshot and hand grenades. Dahlgren was later to report: "Moultrie [sic] fired like the devil, the shells

breaking around us and screaming in chorus" (CWNC III-140). *Chicora*, veteran of the breakout in January, enfiladed the attacking flotilla and contributed to the crushing blow to Union designs on Sumter (CWNC III-140). More than 100 men were taken prisoner, including Lieutenant E. T. Brower and 15 other sailors and marines from *Housatonic* (Porter 1985:447–9; ORN ser. 1:14:617). William Hill, a sailor from the *Powhatan*, and William Beebe, the Officer's Steward from *Housatonic*, were bribed by their Confederate captors and deserted: "...giving all the information in their power regarding the squadron in Charleston. They took their oath of allegiance and are now in the Southern Confederacy" (ONR ser. 1:14:630). Sumter, the key to Charleston, remained in Confederate hands (Figure 2.20).



Figure 2.19. Signalers for Admiral Dahlgren off Georgia. Thanks to the captured *Keokuk* codebook, Confederate forces in Charleston were able to read preparations for the September 8, 1863, small boat attack almost as quickly as they were made (courtesy Library of Congress).

Following the failed assault on Sumter in September, Union operations against Charleston fortifications eased slightly. On the Confederate side, plans moved into high gear to attack one of the Union ironclads that had been the source of such concern to General Beauregard since his July letters to Captain Tucker. Following the breakout of *CSS Chicora* and *Palmetto State* into the blockade fleet in January, the linchpin of the Union blockade had been the most powerful ship in the squadron, *USS New Ironsides*, which took up a nightly position between Confederate forces inside Charleston Harbor and the Union fleet outside. With 10 guns on each side and 4½ in. (11.4 cm)

of armor, *New Ironsides* was the most powerfully armed and effective ship in Dahlgren's blockade fleet (*DANFS* V:58–59). After the war, Beauregard wrote:

I may note that this ironclad threw a great deal more metal, at each broadside, than all the monitors together of the fleet; her fire was delivered with more rapidity and accuracy, and she was the most effective vessel employed in the reduction of Fort Wagner [Campbell 2000:149].

On the night of October 5, 1863, under command of Lieutenant William T. Glassell



Figure 2.20. Confederate defenders of Fort Sumter examine the wreckage outside the walls on September 9, 1863, the morning after the doomed Union attack (courtesy Library of Congress).

(who oversaw salvage of *Keokuk*'s guns in April), the Confederate steam-powered, semisubmersible CSS *David* in a daring surprise attack rammed a 60-pound black powder charge into the hull of USS *New Ironsides* (Figures 2.21 and 2.22).

The explosion threw a huge spout of water into the air and the descending water put out *David*'s boiler fires. In charge of a crippled vessel, Glassell and one of his men abandoned *David* and were captured by the crew of *New Ironsides*. Two other crew members managed to relight the boiler fires and escape back to the safety of Charleston (ONR ser. 1:15:9–10). Damage to the Union ship appeared slight at first, though later a thorough examination in November revealed extensive hull and frame damage (ONR ser.1:15:17–18). Glassell and

the other captured crew member were sent north to be tried and hanged for, as Union newspapers reported, “using an engine of war not recognized by civilized nations” (Campbell 2000:150). Fortunately for Glassell and his compatriot, cooler heads prevailed and they were released as part of a prisoner exchange several months later.

The following day, October 6, 1863, Admiral Dahlgren, impressed by the potential effectiveness of *David*, wrote to Assistant Secretary of the Navy Augustus Fox:

... Among the many inventions with which I have been familiar, I have seen none which have acted so perfectly at first trial. The secrecy, rapidity of movement, control of direction, and



Figure 2.21. Confederate *David*-class semisubmersible in Charleston, 1865. Under the command of Lieutenant William Glassell, the first of the *Davids* very nearly sank USS *New Ironsides* (courtesy National Archives).

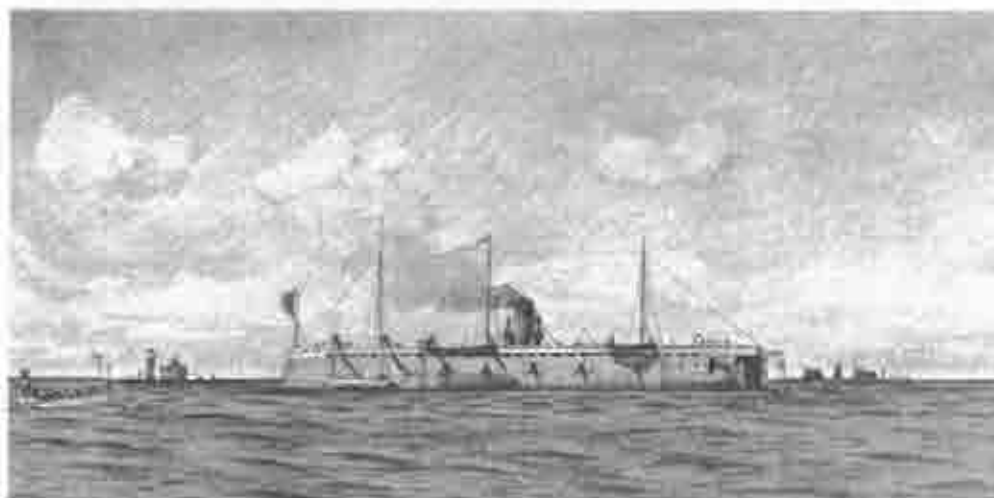


Figure 2.22. Linchpin of the Union Blockade, USS *New Ironsides* (ORN ser. 1:14:605).

precise explosion indicate, I think, the introduction of the torpedo element as a means of certain warfare. It can be ignored no longer. If 60 pounds of powder, why not 600 pounds? [ONR ser. 1:15:10; Figure 2.23].

Alvah Hunter, a ship's boy on the ironclad USS *Nahant*, later wrote in his memoirs:

That this torpedo attack was only partially successful seems to have been due to the fact that the torpedo struck the side of the vessel at a depth of three to four feet below the surface of the water where there was three inches thickness of iron armor. Thus there was ... greater resistance of iron armor, plus the great weight of the ship, than of water above—hence the “geyser” which

went up into the air and very nearly swamped the torpedo-boat.

Had the torpedo been lowered into the water to a depth of, say, ten to twelve feet, it would have been exploded against the hull of the ship and the force of the explosion would have been supported by the great weight of water above it. In this case the frigate would doubtless have gone down in a very few minutes, and torpedo warfare would have taken on a great impetus [Hunter 1987:142].

In Charleston, the results of the *David* attack were similarly analyzed and modifications proposed by Confederate forces—primarily increasing the size of the explosive charge in the torpedo and the depth



Figure 2.23. Second *David*-class semisubmersible in Charleston, 1865. Following the attack in October 1864, Dahlgren feared that Charleston Harbor would swarm with these vessels (courtesy National Archives).

at which it was delivered. These modifications ultimately bore fruit in *Hunley*'s attack against *Housatonic* (Ragan 1999:178; ORN ser. 1:15:20).

On October 15, perhaps spurred by *David*'s near success 10 days earlier, Horace L. Hunley and the rest of the submarine crew renewed training. While practicing attacks on the receiving ship *CSS Indian Chief* inside the harbor, the Confederate sub, under Hunley's command sank in the mud after a series of human errors. Hunley and seven other crewmen suffocated in the submarine.

For the second time in as many months, divers Angus Smith and David Broadfoot recovered the sunken vessel and its dead crew. On November 7, after three weeks on the bottom, the submarine was returned to the surface. Hunley and the rest of the second crew

were retrieved and buried in Magnolia cemetery the next day (Ragan 1995:66, 70).

As the crew was removed from the recovered sub, preparations began for another refit. In December 1863, Lieutenant George Dixon, familiar with the submarine from his time as an engineer in Mobile, was detached from the 21st Alabama Volunteer Regiment and placed in charge of the salvaged, refitted, and newly armed *H.L. Hunley*. Dixon was given instructions that, henceforth, *Hunley* was not to submerge, but instead to attack in the manner of *David*. At the same time a new volunteer crew for the submarine was selected from the *CSS Indian Chief*, the ship beneath which the eight men of the second crew had died (Ragan 1995:90, 96, 100) (Figure 2.24).

While *H.L. Hunley* was undergoing a series of misfortunes, *USS Housatonic* continued to



Figure 2.24. Conrad Wise Chapman's painting of *H.L. Hunley*, made during its refit in December 1863 following the second sinking (courtesy Museum of the Confederacy).

play an active and profitable role in the interception of Confederate blockade runners. On November 5, 1863, *Housatonic* received a 1/13 share of the \$34,144.08 awarded for the capture of the blockade runner *Major E. Willis*, and on December 8, a 1/11 share of the \$14,609.20 awarded for the capture of the blockade runner *Annie Dees*. (Porter 1985:833, 839).

On December 14, 1863, following the refurbishment of the recovered *Hunley*, Lieutenant Dixon and the third crew were ordered by General Beauregard to commence operations against the Union blockade outside of Charleston Harbor:

... First Lieutenant George Dixon, Twenty-First Alabama Volunteers, will take command and direction of the submarine torpedo boat '*H.L. Hunley*,' and proceed to-night to the mouth of the harbor, or as far as capacity of the vessel will allow, and sink and destroy any vessel of the enemy with which he can come in conflict [Ragan 1995:96].

Early attempts from an operations base at Mount Pleasant were unsuccessful throughout the month of December.

A month after the recommencement of operations against the Union blockade, on January 5, 1864, deserters from CSS *Indian Chief* (which had provided the bulk of the third crew for *H.L. Hunley*) informed Admiral Dahlgren of the existence of the submarine. Two days later, Dahlgren issued orders to the blockading squadron detailing precautions to take against Confederate submarine and semisubmersible attack:

I have reliable information that the rebels have two torpedo boats ready for service, which may be expected on the first night when the water is suitable for

their movement. One of these is the *David*, which attacked the *Ironsides* in October; the other is similar to it.

There is also one of another kind, which is nearly submerged and can be entirely so. It is intended to go under the bottoms of vessels and there operate. This is believed by my informant to be sure of well working, though from bad management it has hitherto met with accidents, and was lying off Mount Pleasant two nights since.

There being every reason to expect a visit from some or all of these torpedoes, the greatest vigilance will be needed to guard against them. The ironclads must have their fenders rigged out and their own boats in motion about them.

A netting must also be dropped overboard from the ends of the fenders, kept down with shot, and extending along the whole length of the sides; howitzers loaded with canister on the decks and a calcium for each monitor. The tugs and picket boats must be incessantly upon the lookout, when the water is not rough, whether the weather be clear or rainy [ORN ser. 1:15:226–227].

With the inner, ironclad, cordon of the blockade exercising stricter precautions against attack, Dixon and his crew shifted their focus to elements of the Union fleet further offshore (Figure 2.25). Initially, Charleston's two secret weapons, *Hunley* and *David* worked together to attack the blockade with *David* towing *Hunley* into attack range. In early January while under tow, *Hunley*'s trailing torpedo fouled the CSS *David*. Had the contact fuses on the torpedo exploded it would have set off the black



Figure 2.25. Disposition of the blockade as of early winter 1864.

powder charge and destroyed both vessels, but the crew cleared it after several tense moments. Following this near miss, Captain Tucker refused to allow *David* to tow *Hunley* into action. Forced to rely exclusively on the power provided by its crew, Dixon and his crew relocated to Breach Inlet, between Sullivan's Island and Isle of Palms, to be closer to the softer targets of the outer ring of the blockade (Ragan 1995:104).

At the beginning of 1864, the fate of Charleston was becoming apparent to all concerned. With Morris Island under Union control and Charleston under continual bombardment from batteries between Morris and James Island, things began to look grim for the defenders of the "Cradle of Rebellion." As the prospect of victory became more tangible, Admiral Dahlgren found himself increasingly on the political defensive from Washington, DC

politicians that couldn't seem to understand why Charleston continued to resist. On January 22, 1864, Dahlgren wrote to Assistant Secretary of the Navy Gustavus Fox:

My Dear Fox: Your note of the 12th January came very acceptably. I will make a report on the monitors as soon as possible; but do not suppose that I am idle because no battles are fought; on the contrary, the blockade by four monitors of such a place as this, and the determined intentions of the rebels to operate with torpedoes, keep all eyes open. The monitors have submerged nets fore and aft, and the whole space in front of them is patrolled by tugs and cutters. I am always on hand myself after sunset. It is a faithful and most trying work for the monitors, and I can

assure you that a battle would be a relief to us all, to none more than myself [ORN ser. 1:15:254].

Dahlgren was to get his relief, but not in the battle that he wished for.

ATTACK

"Enterprise, even with scant means, can accomplish much"
Charleston Mercury, 7 May 1863

It is apparent from his writings throughout fall and early winter 1863–1864 that the possibility of Confederate torpedo attack weighed heavily upon the mind of Admiral Dahlgren. As an engineer and a military officer, the tactical and strategic implications of torpedoes, the *David* and *Hunley* were not lost on him. Dahlgren had been in discussions with Professor Benjamin Maillefert as early as August 1863 about methods to remove torpedoes from the harbor entrances prior to attacks against Charleston (ORN ser. 1:14:428), and his appreciation of the potential for submarine warfare had been conveyed to Secretary Welles that same month (ORN ser. 1:14:435). The information sent to Dahlgren by Union spies in the Bahamas and Confederate deserters from Charleston did nothing to lessen his apprehension. From his orders to the squadron, one can see that he shared his concerns with the squadron. On February 17, 1864, the attack that he feared and planned against finally occurred—a long chain of intentions, coincidences and designs came together with catastrophic and historic results.

Early February 1864, was a stormy period for the blockade squadron and Union vessels sheltered in Lighthouse Inlet at night (Ragan 1999:190). For Lieutenant Dixon and his crew, the spell of bad weather probably came as a

relief from the heavy physical duty of cranking *Hunley* miles offshore and back several nights per week (Ragan 1999:190). Finally, after several days of storms, on the morning of February 17, the low-pressure system moved offshore, and calm returned outside Charleston Harbor. With the return of fair weather, the *H.L. Hunley* crew renewed their efforts to destroy a Union ship.

Though nothing has surfaced in the archives, it is interesting to note that, just as the Union gained tremendous intelligence from Confederate deserters such as those from *Indian Chief*, the Confederacy's prime source for information concerning the blockade came from Union deserters. Following the abortive attack by small boats against Sumter in November 1863, the *Housatonic's* Officer Steward William Beebe, had divulged everything he knew about the Union blockade. The Confederate defenders of Charleston were, therefore, in a position to know more about *Housatonic* than any other ship in the squadron. Dixon's probable knowledge of *Housatonic*, its choice as a target, as well as his point and method of attack, may well be more than just an historical coincidence or consequences of opportunity.

At about 6:00 P.M. on the night of February 17, 1864, *H.L. Hunley* and a crew of eight, commanded by Lieutenant George Dixon slipped out to sea on the ebb tide through Breach Inlet. *Housatonic*, back on station after two days of miserable weather, sat outside the inner ironclad cordon of the blockade just south of Rattlesnake Shoal. USS *Housatonic* rode easily, laying at anchor northwest by west $\frac{1}{2}$ west in calm seas with winds northwest by west and the tide setting northeast at about 1 kn. (Bak 1999:162). Under a bright moon, *Hunley* aimed for the Union sloop-of-war.

Though *Housatonic* did not deploy boom nets and picket boats like the inner cordon of the blockade, standing orders issued by Admiral

Dahlgren required that 25 pounds of steam be kept in the boilers, the anchor be ready for slipping and a full watch be kept at all times (Bak 1999:162). Orders aside, *Housatonic's* crew had a strong financial incentive for being prepared—the men on board had already shared thousands of dollars in prize money from the capture of blockade runners like *Princess Royal* and *Annie Dees*.

At approximately 8:45 P.M., Acting Master John Crosby saw what he thought was a porpoise surfacing to blow at a distance of 45–100 yards off the starboard beam. Calling to the quartermaster to confirm what he saw, he noticed the object turn and head directly at the anchored *Housatonic*. As *Hunley* approached at a speed of 3–4 kn., Crosby called for the captain, and gave the order to beat to quarters, slip the chain and back the engine to escape the attacking submarine (Bak 1999:153–154).

At the same time that Crosby was sounding the alarm, Acting Master's Mate L. A. Corinthwait also saw the object with glasses from the bow and hurried to the stern to report to Crosby. Having reported the object, he returned to ensure that the anchor chain was slipped to allow *Housatonic* to back (Bak 1999:161).

About one minute after Crosby sounded the alarm, at 8:46 P.M., Captain Pickering emerged from his cabin and assumed command. As *Hunley* approached, the *Housatonic* crew attempted to train a cannon on the submarine but could not lower the muzzle enough. The sailors on deck opened up with small arms and several muskets were fired at the attacking submarine. At the same time, Captain Pickering fired on it with his shotgun (Bak 1999:154).

Less than a minute later, *Housatonic* slipped its chain and backed its engine in an attempt to avoid the attacking submarine (Bak 1999:157). Assistant Engineer C. F. Mayer heard the three

bells rung as an alarm and saw the engine immediately backed. After about three or four revolutions (about six seconds), *Hunley's* charge exploded, and *Housatonic's* engine raced as if the propeller shaft had been sheared (Bak 1999:164) (Figure 2.26).

As *H.L. Hunley* moved in for the final attack run, observers on the ship reported that *Hunley* changed course and moved towards the stern—this would place the torpedo squarely in *Housatonic's* most vulnerable region near the powder magazines. As *Hunley* closed, both Master's Mate L. A. Corinthwait and Lieutenant F. J. Higginson reported that the submarine moved parallel and astern of *Housatonic's* keel before turning to ram the torpedo into the stern (Bak 1999:161, 162).

At approximately 8:47 P.M., two minutes after Crosby and Corinthwait's initial sighting, *Hunley* rammed its explosive charge into the starboard side of *Housatonic* just astern of the mizzenmast (Bak 1999:154). Under fire from pistols, muskets and shotguns, the Confederate vessel backed away to a distance of 40 or 50 ft. (12.1 or 15.2 m) and then tripped the lanyard to explode the torpedo (Bak 1999:158). Landsman Robert Flemming's account differs slightly, and he reports to the subsequent Court of Inquiry that *Hunley* was only 6 or 8 ft. (1.8 or 2.4 m) from the starboard quarter following the explosion (Bak 1999:164). There was a loud, but not tremendous, explosion, and a large column of black smoke rose from the stern. There is no account of a column of water or flames from the blast, but Acting Master Joseph W. Congdon reported pieces of deck aft of the mizzenmast blown into the air, and Master's Mate L. A. Corinthwait later stated that pieces of the deck were thrown into the air as high as the mizzen top. Lieutenant Higginson reported a column of black smoke coming out of the Number 7 gunport, forward of the mizzenmast (Bak 1999:160, 161).



Figure 2.26. Contemporary pencil sketch of the *Hunley* attack (courtesy Library of Congress).

After the blast, at approximately 8:48 P.M., *Housatonic* filled rapidly with water and settled stern first on the bottom. Ensign C. W. Craven reported that following the explosion, the ship:

... was sinking very rapidly aft. Almost immediately she gave a lurch to port, and settled on the bottom. Afterwards, in looking for the body of Mr. Hazeltine, I saw the starboard side of the quarterdeck abaft the mizzen mast, and the furniture of the wardroom and cabin were floating within the ridge rope so I supposed the whole starboard side of the ship aft the mizzen mast was blown off. I heard a report like a distant firing of a howitzer. The ship went down by the stern, and about three or four minutes after the stern was submerged, the whole ship was submerged [Bak 1999:159].

As the ship hit the floor of Charleston Harbor, it lurched heavily to port (Bak

1999:154, 160). Acting Master Congdon reported that *Housatonic* was completely submerged within 3 minutes of the explosion, though Ensign C. W. Craven reports that from the time of the explosion until the time of sinking was approximately 5 minutes (Bak 1999:158, 160). While the Union sloop was sinking, five of its crew perished either by drowning or as a direct result of the blast (Bak 1999:172). The rest of the crew scrambled into the rigging and awaited rescue from the other ships of the blockading squadron.

At 9:20 P.M., the first boat from *Housatonic* arrived at *Canandaigua* requesting help for the survivors (ORN ser. 1:15:327–328). On August 26, 1862, *Canandaigua's* Captain, Joseph W. Green, had rescued the crew of USS *Adirondack*, which had wrecked while patrolling for the Confederate raider CSS *Oreto* off the Bahamas, and for the second time in as many years, Green rescued the crew of an *Ossipee*-class sloop-of-war (ORN ser. 1:13:422–424).

At approximately 9:35 P.M., 50 minutes after the attack, Landsman Robert F. Flemming

reported seeing a blue light (*Hunley's* signal to land of a successful attack) in the water off the starboard side of *Housatonic*: "When the *Canandaigua* got astern, and lying a thwart of the *Housatonic*, about four ships lengths off, while I was in the fore rigging, I saw a blue light on the water ahead of the *Canandaigua*, and on the starboard quarters of the *Housatonic*" (Bak 1999:165; ORN ser. 1:15:327-328). Confederate documents offer independent confirmation of Flemming's report. On February 19, two days after the attack, Lieutenant Colonel Danzler at Battery Marshall at Breach Inlet submitted the following report to headquarters:

Lieutenant: I have the honor to report that the torpedo boat stationed at this post went out on the night of the 17th instant (Wednesday) and has not yet returned. The signals agreed upon to be given in case the boat wished a light to be exposed at this post as a guide for its return were observed and answered. An earlier report would have been made of this matter, but the officer of the day for yesterday was under the impression that the boat had returned, and so informed me. As soon as I became apprised of the fact I sent a telegram to Captain Nance, assistant adjutant-general, notifying him of it.

Very respectfully,

O. N. DANTZLER,
Lieutenant Colonel
[ORN ser. 1:15:335]

H.L. Hunley was not seen for 131 years. Ironically, on February 18, as *Housatonic* lay destroyed on the floor of Charleston Harbor with five dead, the ship's crew was awarded a 1/12 share of the \$17,685.69 handed out for the capture of the blockade runner *Secesh* (Porter 1985:842).

AFTERMATH

Dahlgren's fears had been realized with the successful attack of *Hunley* against *Housatonic*, and in the aftermath of the engagement he struggled to devise a counter to the new threat. On February 19, 1864, two days after the attack, he wrote to Secretary of Navy Welles:

The Department will readily perceive the consequences likely to result from this event; the whole line of blockade will be infested with these cheap, convenient, and formidable defenses, and we must guard every point. The measures for prevention may not be so obvious.

I am inclined to the belief that in addition to the various devices for keeping the torpedoes from the vessels, an effectual preventive may be found in the use of similar contrivances. ... I have attached more importance to the use of torpedoes than others have done, and believe them to constitute the most formidable of the difficulties in the way to Charleston. Their effect on the *Ironsides*, in October, and now on the *Housatonic*, sustains me in this idea [ORN ser. 1:15:229-230].

Dahlgren also ordered the inner blockade ring to move outside of Charleston Harbor and to keep underway at night as a defensive measure (ORN ser. 1:15:230). The immediate tactical effect of *Hunley's* attack was to loosen the stranglehold that the Union had on the Cradle of Rebellion. In January 1863, Captain C. O. Boutelle of the Coast Survey had written to Captain Stellweger: "Captain Taylor desires me to say that he is very willing that the *Ottawa* should cross the bar and anchor inside at night, on my assurance that his vessel runs no risk of

being entrapped while she effectually stops that 'rat hole' " (ORN ser. 1:13:554).

In February 1864, at least for a little while, the "rats" that *Ottawa* had stopped up in Charleston the previous year were widening their hole to the benefit of ongoing efforts to run the blockade. In the longer term, the necessity of keeping the Union fleet moving throughout the night around the shifting shoals of the harbor increased the strain on men already stretched taut by months of arduous duty. The ships of the blockade also suffered, and unable to stop movement, Union crews experienced greater difficulty maintaining and repairing their machinery—just as the USS *Pembina* had in 1862. While ultimately *Hurley's* attack had only minor consequences in the overall course of the blockade, in the weeks and months that followed, the specter of squadrons of submarines loomed large in the minds of Union planners and increased the costs to the Union of maintaining the blockade.

SALVAGE

Efforts to recover items of value from the wreck of *Housatonic* began from *Canandaigua* February 20, 1864 (ORN ser. 1:15:832). That same day, Captain Green made the following report to Commodore Rowan, the ranking officer present in Charleston:

I have examined the wreck of the *Housatonic* this morning and find her spar deck about 15 ft. below the surface of the water. The after part of her spar deck appears to have been entirely blown off.

Her guns, etc., on the spar deck, and probably a good many articles below deck, can, in my opinion, be recovered by the employment for the purpose of the derrick boat and divers [ORN ser. 1:15:331].

On February 26, 1864, divers prepared for salvage work on the *Housatonic* wreck, with the guns being a priority. Commodore Rowan wrote orders to one of his subordinates requesting his assistance with the salvage operation:

Sir: The divers will see you this morning in relation to making preparations to remove such public property from the *Housatonic* as can be recovered. To this end you will please afford them all the facilities of your command. I would suggest that the *Mary Sanford* or *Nipsic* could attend them during the day and put them on board the *Geranium* in the evening to return to their schooner inside. When the guns, etc., are all slung ready for hoisting please inform me [Record Group 45, M625, Area 8, Reel 208, National Archives].

Salvage operations continued during February and into March. The *Charleston Mercury* reported on salvage efforts throughout the period: "Thursday, March 3, 1864, the enemy are engaged on the wreck of the *Housatonic*, endeavoring to raise the armament of the sunken vessel. ...Friday, March 4, 1864, a schooner with a derrick was alongside of the sunken steamer *Housatonic* all day yesterday endeavoring to raise her guns." On March 15, 1864, the *Charleston Daily Courier* reprinted a letter from the *Boston Herald* describing the attack and the condition of the wreck:

... At low tide the water is about six feet above the rail of the '*Housatonic*.' If the weather moderates her guns, and many valuable articles and the pay masters safe will be recovered. She cannot be raised, as her stern is

completely blown off, clean to the ward room hatch. She was loaded down with coal and provisions, which will be a total loss....

The same day, Union Secretary of the Navy Gideon Welles was sent the following report concerning the salvage efforts:

Sir: I have the honor to report that the two pivot guns, carriages and slides, etc. complete, and four 32-pounders and carriages, have been recovered from the wreck of the '*Housatonic*' by means of the divers and a steam derrick. The divers and derrick can work only in smooth water, and as the expense attending the employment of the means is heavy (two hundred dollars per day for the derrick), I think it will be best not to attempt to recover the 30 pound Parrott guns, unless a smooth day occurs before the derrick can be discharged [Letters Received by Squadron Commanders, National Archives].

Recovery efforts ran through the late winter and early spring 1864, as the services of the divers could be spared from their other duties (ORN ser. 1:15:334). Though the guns were recovered, it is apparent that a considerable amount of the ship remained intact. On September 24, 1864, eight months after the attack, the Union blockade ship USS *Mingoe* fouled the wreck of *Housatonic* while underway outside the Charleston bar (ORN ser. 1:15:688).

The following month, diving operations on the wreck picked up pace. On November 26, 1864, the *Charleston Mercury* reported divers at work on *Housatonic*; and on November 27, 10 months after the attack, Lieutenant W. L.

Churchill reported to Admiral Dahlgren on the condition of the wreck:

After a careful examination of the wrecks of the sunken blockade runners and *Housatonic*, I have the honor to make the following report:

I find that the wrecks of the blockade runners are so badly broken up as to be worthless. The *Housatonic* is very much worm-eaten, as I find from pieces which have been brought up. She is in an upright position; has settled in the sand about 5 feet, forming a bank of mud and sand around her bed; the mud has collected in her in small quantities. The cabin is completely demolished, as are also all the bulkheads abaft the mainmast; the coal is scattered about her lower decks in heaps, as well as muskets, small arms, and quantities of rubbish.

I tried to find the magazine, but the weather has been so unfavorable and the swell so great that it was not safe to keep a diver in the wreck. I took advantage of all the good weather that I had, and examined as much as was possible.

The propeller is in an upright position; the shaft appears to be broken. The rudderpost and rudder have been partly blown off; the upper parts of both are in their proper places, while the lower parts have been forced aft. The stern frame rests upon the rudderpost and propeller; any part of it can be easily slung with chain slings, and a powerful steamer can detach each part.

I have also caused the bottom to be dragged for an area of 600 yards around the wreck, finding nothing of the torpedo boat. On the 24th the drag ropes caught something heavy (as I reported). On sending a diver down to examine it, proved to be a quantity of rubbish. The examination being completed, I could accomplish nothing further, unless it is the intention to raise the wreck or propeller, in which case it will be necessary to have more machinery [ORN ser. 1;15:334].

With the war coming to a close, the need for materials began to diminish, and diving operations slowed and then ceased.

On February 17, 1865, one year to the day after the sinking of *Hunley* and *Housatonic*, the city of Charleston was evacuated after 567 days of continuous siege. That same day, General Sherman's army occupied Columbia, the state capital, and South Carolina's role in the war effectively came to an end (Johnson 1890:xx). In an ironic twist in a war full of irony, Major Anderson, the Union officer in charge of the Sumter garrison in April 1861, returned to the fort and raised the Stars and Stripes over the shattered bastion on April 14, 1865—four years to the day from when he had lowered them in surrender (Burton 1970:61).

On January 24, 1861, the *Charleston Mercury* had trumpeted that: "The fate of the Southern Confederacy hangs by the ensign halyards of Fort Sumter"—that these words should return in such bitter form speaks volumes to the destruction of Southern hope in the closing months of the Civil War.

On March 1, 1865, just six weeks before Lee's surrender at Appomattox, divers were again at work on the wreck of *Housatonic* and reported the recovery of the paymaster's safe to Gideon Welles: "Sir: I have sent by the USS

Massachusetts the '*Housatonic's*' money safe recovered by the divers with instructions that it shall be delivered to the Department for such dispositions as may be ordered in the case" (Letters Received by the Secretary of the Navy from Squadron Commanders, National Archives).

EPILOGUE

In the years that followed the Confederate surrender, the wreck of *Housatonic* remained undisturbed—part of the detritus of war clogging the mouth of Charleston Harbor. Devastated by the conflict, the city stagnated for years, unable to attract or produce capital or political support sufficient for the reconstruction of the once busy port (Moore 1980:30).

In 1870, the Army Corps of Engineers under the command of General Quincy Gillmore (Dahlgren's army counterpart during the siege of Charleston) began initial preparations for the resurrection of Charleston Harbor and the resumption of dredging efforts that had commenced as early as 1857 (Moore 1981:20) (Figure 2.27). On April 20, 1870, Captain Ludlow submitted a report concerning the state of the *Housatonic* wreck: "The wreck has been blasted, the stem blown off and portions of the machinery taken out. Two boilers are still in her weighing 40 and 50 tons each. The wooden sheathing inside and the flanking [sic] outside are eaten by worms down to the copper. It is a dangerous wreck lying in deep water in the track of northerly bound vessels, and should be removed" (Miscellaneous Wrecks, 1871–1888, RG 77, File #1125, National Archives, Southeast Region).

On September 20, 1872, Ludlow's recommendations were put in action, and the Corps of Engineers accepted a bid from Admiral Dahlgren's former torpedo engineer, Professor



Figure 2.27. Union General Quincy Gillmore, commander of the ground forces during the siege of Charleston and director of Charleston Harbor's reconstruction. Gillmore's construction of the harbor jetties directly affected the wrecks of both *Hunley* and *Housatonic* (courtesy Library of Congress).

Benjamin Maillefert, for the removal of the wrecks *Weehawken* (which had sunk at anchor on December 6, 1863) and *Housatonic*, as well as the missing submarine boat *Hunley*, if the wreckage could be found (*CWNC* III:161; Miscellaneous Wrecks, 1871–1888, RG 77, File #1125, National Archives, Southeast Region) (Figure 2.28).

Throughout winter and spring 1873, Maillefert's divers carefully surveyed the

Housatonic wreck in preparation for more extensive work that summer (Annual Report of Chief of Engineers 1873:729). In June, salvage of copper, brass, iron and lead from the wreck commenced in earnest, and Maillefert's logbooks provide an ongoing glimpse of the pace and nature of the work:

June 17, 1873. '*Dreadnaught*' flat over the wreck of the *Housatonic*. Captain Fairchild in charge ... June 19, 1873. '*Dreadnaught*' over the wreck of the *Housatonic* ... June 20, 1873. '*Dreadnaught*' on the *Housatonic* ... June 23, 1873. '*Dreadnaught*' nearly finished over the wreck of the '*Housatonic*.' Will return to the city in a day or two. Capt. Fairchild returned to the flat yesterday (Sunday) morning ... June 24, 1873. '*Dreadnaught*' waiting to get the result of survey over the wreck of the '*Housatonic*', when 20 feet is required by contract ... June 28, 1873. '*Dreadnaught*' brought up this a.m. had on it considerable copper, brass, lead, two tanks and some little angle iron. Unloaded her wrecking material; all placed in storehouse" [Maillefert's Salvage logs, South Carolina Historical Society].

On August 28, 1873, General Gillmore was informed that the terms of the contract had been fulfilled: "The wooden gun-boat '*Housatonic*' sunk outside the bar in 4½ fathoms of water, was removed to a low water depth of 20½ ft. (6.2 m). The torpedo-boat, sunk at the same time and place, could not be found" (1873 Annual Report of Chief of Engineers. pg. 728). Though the contract had been completed, Maillefert's salvage activities on the wreck continued for another year: "April 17, 1874, '*Josephine*' after working a little on the



Figure 2.28. Union Captain Professor Benjamin Maillefert (center) and officers at the torpedo station on the James River Virginia, 1865. Maillefert was an important player in the development of Union torpedoes and torpedo countermeasures and was to later oversee the salvage of the *Housatonic* wreck (courtesy National Archives).

"*Housatonic*" wreck, returned at noon today to Johnson's wharf, bringing with her about 500 lbs. copper bolts, more or less . . . August 28, 1874, *Dreadnaught over Housatonic*" (Maillefert's Salvage logs, South Carolina Historical Society).

In 1876, with major wrecks largely removed, General Gillmore finalized a plan for the improvement of Charleston Harbor incorporating construction of two large, stone jetties at the harbor mouth to funnel ebb tidal flow and scour a shipping channel (Moore 1981:32). The following year, South Carolina Senator John Patterson appropriated \$200,000 to begin the work (Moore 1981:33).

Jetty construction proceeded steadily, and by 1882, 17 years after the cessation of hostilities, the Charleston Chamber of Commerce was able to publish a study showing foundations of the north jetty almost completed and those on the south jetty about one-third done (Moore 1980:34). In 1885, the Corps began dredging a

channel through the Charleston bar, and by 1886, the foundations for both the north and south jetties had been completed (Moore 1980:36). In 1888, specifications for harbor improvement were changed to include dredging a navigational channel at least 350 ft. (106.7 m) wide and 15 ft. (4.6 m) deep at mean low water and raising the outer tips of the jetties to concentrate ebb tidal current for channel maintenance (Moore 1980:36). By 1895, jetty construction was finished at a cost of approximately 3.9 million dollars and declared a complete success—the concentration of ebb tidal flow produced sufficient current to keep the channel that has been dredged through the bar clear to a depth of 17½ ft. (5.3 m), and shipping now had a direct path into and out of Charleston Harbor (Moore 1980:39). Sediment transport patterns throughout Charleston Harbor changed dramatically as a result of jetty construction, and this had a direct impact on the wrecks of both *Housatonic* and *Humley* (Chapter 8).

The *Housatonic* wreck remained undisturbed and marked by a buoy for more than 30 years; but by 1908, plans emerged to further lower the wreck and remove it as a hazard to navigation. On July 12, 1908, the *Charleston News and Courier* published a brief article detailing work to be done on the wreck:

Diving for the '*Housatonic*,' an historic derelict at entrance of harbor. Thorough investigation has been made by the force of divers who were sent here this week by the Merrit & Chapman Wrecking and Dredging Company, of Norfolk, of the wreck of the frigate '*Housatonic*,' which was sunk in the harbor by a Confederate torpedo boat in 1864...most of her timbers have disappeared, having been washed away by storms. Among things seen below were two boilers and much of the armament of the old time battle ship, and it is thought that a good amount of salvage can be obtained from the old iron that can be easily gotten out of the old fighting machine. Should the '*Housatonic*' be removed, dynamite will be used in great quantities, and the last death of the old reminder of the War Between the States will be a grand sight.

On January 15, 1909, a contract to remove what was left of *Housatonic* was awarded to diver William Virden of the Beaufort, South Carolina, firm Claghorn and VonHarten, and the following month a survey of the wreckage was begun prior to final demolition. Following completion of the survey, the two boilers of *Housatonic* were blasted and buried in the sand. From the 1909 Annual Report of the Chief of Engineers (under the heading "Removing Sunken Vessels or Craft Obstructing or

Endangering Navigation") comes the following description of the work performed by Virden and his diving company:

Removing Sunken Vessels or Craft Obstructing or Endangering Navigation Removal of U. S. S. *Housatonic* in Charleston Harbor, South Carolina. The *Housatonic* was a wooden man-of-war, belonging to the blockading squadron stationed off Charleston Harbor during the Civil War. The wreck was cut down by the government to a depth of 20 feet below mean water soon after the war.

An examination of the wreck was made at a cost of \$395.85; it was found that portions of the wreck still remained, and its position being very near the course of vessels entering or leaving the harbor, recommendation was made for the removal of the obstruction so as to leave a depth of 27 feet at mean low water, estimating the cost at \$12,000 dollars. Allotment of this sum was made September 14, 1908. Proposals were invited, and opened on November 21; award was made to the lowest bidder, William H. Virden, Lewes, Del., and a contract dated January 18, 1909, was approved by the Chief of Engineers on February 16, 1909.

Work was begun by the contractor on February 19. Under the provisions of the contract he was allowed to cut the wreck down without removing the pieces, if it should be found practicable to do this. He adopted this plan and blasted the boilers, which were

practically all that remained of the wreck, breaking them into pieces. He then announced that the contract had been completed. Examination by sweep proved that the required depth had not been obtained and the contractor was directed to resume work. He did more blasting and again called for an examination.

After repeating this process several times, the contractor reached the conclusion that it was necessary to remove the broken pieces of boiler, which he did. After removing about four tons of old iron, mainly boiler iron, he again called for an examination, which was made, with the result that nothing above the required depth of 27 feet below mean

low water was found. The contractor was then notified of this result, and removed his plant. Settlement has not been made for this work. The expenditures for this work were \$826.57 [Annual Report of the Chief of Engineers 1909:1316].

Following work in 1909, no other major salvage was done on the remains of *Housatonic*. At some point, the buoy that marked the wreck as a hazard to navigation sank. *Hunley*, *Housatonic* and the buoy all went through the same pattern of scouring, settling, and rapid burial caused by the new sedimentary and tidal dynamics generated by construction of the Charleston jetties. Three components of an historic naval engagement and its aftermath lay waiting for excavation and documentation by archeologists.

CHAPTER 3

Research Design

David L. Conlin

PREVIOUS WORK

DISCOVERY

On May 3, 1995, archeologists sponsored by author Clive Cussler successfully located the wreck of *H.L. Hunley*. In 1996, at the request of the Naval Historical Center (NHC), the National Park Service Submerged Resources Center (NPS-SRC), the South Carolina Institute of Archeology and Anthropology (SCIAA), and archeologists from the US Navy, NHC Underwater Archaeology Branch returned to coordinates furnished by Cussler's team to: 1) confirm the identity of the object located as the wreck of *H.L. Hunley*; 2) assess the condition and preservation of the wreck; and 3) make a recommendation based upon that assessment for future management of the wreck (Lenihan and Murphy 1998:15).

1996 PREDISTURBANCE SURVEY

Before exposing the *Hunley* site for documentation and evaluation in 1996, a predisturbance remote sensing survey was conducted over an area that included both the location of the *H.L. Hunley* wreck and the historically known site of *Housatonic*. Systematic remote sensing with towed instrumentation produced a synoptic overview of known and potential cultural remains and relationships within the study area prior to excavation (Murphy et al. 1998:45–62).

The 1996 predisturbance survey was designed to produce a comprehensive data set that would be immediately accessible to managers and researchers for planning and to aid interpretation during excavation. The survey design was based upon the wide-area archeological survey methodology developed

during the NPS System-wide Archeological Inventory Program (SAIP) survey of Dry Tortugas National Park, which began in 1993 (Murphy et al. 1997; Murphy and Smith 1995; Shope et al. 1995). Remote sensing instrumentation used for the 1996 predisturbance survey included: magnetometer (locates ferrous cultural material possibly representing archeological sites by detecting local variations in the earth's magnetic field); survey depth sounder (determines water depth); sub-bottom profiler (records geological stratigraphy below the seabed); RoxAnn bottom classification device (characterizes surficial seabed sediments); and side scan sonar (generates a topographic rendition of the seabed and cultural materials on and above it) (Murphy et al. 1998:45). Utilization of these sensors concurrently provided a multiparameter natural and cultural resource hydrographic survey to address goals set forth in the 1996 research design (Lenihan and Murphy 1998:15).

From the outset of the 1996 assessment, the wrecks of *Hunley*, *Housatonic* and associated remains were approached as different components of a single, multicomponent site. Comprehensive remote sensing of the area containing all components was conducted in a manner so as to produce a Geographic Information System (GIS) database useful to immediate and long-term site management. GIS, long an important tool for the NPS-SRC, allowed for rapid data analysis during the 1996 *Hunley* project and later incorporation into permanent South Carolina and federal archives. A GIS approach resulted in an electronic database that could incorporate available digital data, such as aerial imagery and digitized historical maps, so they could be combined with project-specific results and be analytically manipulated to examine relationships that would otherwise be extremely difficult to observe. The project GIS data set was generated to provide a

standardized, permanent, cumulative, computer-accessible product for multiple applications of project researchers, managers and those involved in planning and conducting future site operations. This existing data set will form the groundwork for the research planned for this summer.

The 1996 high-resolution survey located cultural materials and characterized the environmental context of both *Hunley* and *Housatonic*. These data were used at that time to assist operational and interpretive objectives. Developing a remote sensing-derived site perspective prior to beginning test excavation was important for planning to ensure related features near the principal components were recognized and investigated and so that stratigraphic sequences and subsurface scour features would be recognized and identified. Location of outlying ferrous masses possibly associated with *Hunley*, or perhaps related to the *Hunley-Housatonic* engagement, was also an objective (Lenihan and Murphy 1998:15–16; Murphy et al. 1998:45). Although magnetic anomalies, indicative of cultural remains, were located during the 1996 survey, they were not investigated at that time.

1996 HUNLEY EXCAVATION

During the test excavation of *H.L. Hunley* in 1996 for assessment purposes, hand-driven cores were taken near the site and in proximity to determine ambient sedimentary conditions. Core analysis included stratigraphic profiling, sediment composition, pollen count, and ^{210}Pb radiometric dating.

In addition to a classification of the sedimentary environment around *Hunley*, biologists from the South Carolina Department of Natural Resources examined corals and oysters on the hull of the submarine to provide an additional line of evidence for burial sequence

and site formation processes (Murphy, Russell and Amer 1998:95–98; Appendix C).

HOUSATONIC RESEARCH GOALS

OVERVIEW

The following is the body text of the research design as written prior to commencement of operations.

This research design addresses tasks and rationales for the 1999 summer field season on submerged archeological materials potentially related to the Confederate submarine *H.L. Hunley* and USS *Housatonic*. Work will be a continuation and amplification of research foci established in 1996, and it will add new data to the 1996 GIS data set. The 1999 fieldwork concentrates first on the remains of *Hunley's* victim, the Union blockade ship *Housatonic*, and second on the magnetic anomaly close to the wreck of the submarine known as the “Third Anomaly.” A fourth magnetic anomaly (the “Fourth Anomaly”) located north of the Third Anomaly will be examined and evaluated if time and resources allow. Additional minor work on *Hunley* may be undertaken to augment data recovered in 1996. The current fieldwork is broadly conceived as a National Historic Preservation Act Section 110 assessment of the components of a naval battle site to determine its eligibility to the National Register of Historic Places.

This project is designed to augment what is currently known about the battle between *H.L. Hunley* and USS *Housatonic*. Placing *Hunley* in a broader historical and archeological context will result in a more thorough understanding of the battle and will assist in archeological interpretation and subsequent public understanding of this site and the studies that have been done on its different components. Locating and making an archeological

assessment of the nature and extent of materials related to the USS *Housatonic* as well as the Third and Fourth Anomaly are necessary steps in this process. The historical and archeological significance of *Hunley* is, in part, derived from its relationship with *Housatonic* and vice versa. *Hunley*, while the most celebrated component of the naval battle site, is only one element of the total picture to be documented in order to interpret and understand the encounter between the Union and Confederate naval forces in its fullest possible archeological and historical context.

SPECIFIC OBJECTIVES

USS HOUSATONIC

An initial characterization of USS *Housatonic* will be made to evaluate the wreck's archeological integrity and potential for National Register eligibility. Goals of this part of the survey are to identify key features of the ship, the extent of the wreckage, and vessel orientation in a manner that minimally impacts the vessel remains. If the site possesses archeological integrity, present and future work may be able to interpret the ship's construction, spatial organization and possible battle damage. Documenting battle damage resulting from the *Hunley* attack is also a goal of this research, but this cannot be satisfactorily achieved until the subsequent processes affecting the wreck, such as salvage and decay, have been taken into account. This research has been designed to produce a basic understanding of the *Housatonic* site upon which future research can be built.

Housatonic was salvaged in 1864–1865 and 1873–1874, then dynamited and dragged in 1909. These processes may have scrambled the wreck considerably. Understanding the wreck in its present state will be a multidisciplinary effort, although based on archeological evidence,

it will include an examination of the biological growth (such as coral) on *Housatonic* [this was not possible due to limited excavations and a lack of biological growth on excavated areas] and on a stratigraphic analysis of sediments over and underlying hull structure. Isotopic, pollen and physical characterization of sedimentary stratigraphy should give an idea of the nature and extent of postdepositional salvage episodes and site formation processes [pollen analysis was not done]. Test trenching to ascertain the ship's orientation and state of preservation, burial sequence(s) and artifactual preservation will be conducted as part of the 1999 fieldwork. Only artifacts at risk or those that will provide significant interpretative information about the site will be recovered. Artifacts will be stabilized in the field and transported immediately to the conservation facility for detailed analysis and further conservation.

ARTIFACTS

Recovered artifacts will be conserved at the NHC's Conservation Laboratory or, alternatively, the SCIAA laboratory depending on nature of materials and facility capabilities [all artifacts were conserved at NHC in Washington, DC]. Project conservator Claire Peachey will have overall responsibility for artifacts, including field stabilization, documentation, transportation and selection of laboratory facility and procedures. All archeological materials and documentation will be permanently curated at the Charleston Museum [the collection is curated at NHC].

OUTLYING MAGNETIC ANOMALIES

The successful attack of *H.L. Hunley* on the Union blockade ship *USS Housatonic* has created an archeological site with two principal

components—the wrecks of *Hunley* and *Housatonic* and two unknown elements distinguished by magnetic anomalies—that were documented during remote sensing operations in June 1996. These anomalies may or may not be related to either or both wrecks or to other activities related to the engagement. An important part of this project is to ascertain the nature and relationship of the unknown elements to the two principal components. This approach was recommended in the 1996 *Hunley* Assessment (Murphy, Lenihan and Amer 1998: 121).

Third Anomaly

The Third Anomaly will be relocated and examined via test excavation. The basic question is whether or not this feature is related to *Hunley*, *Housatonic* or neither. If possible, all materials uncovered will be documented through direct measurement, drawing, photography and video [poor water conditions made it impossible to document the Third Anomaly with video and photography]. A stratigraphic/isotopic sequence and pollen stratification analysis of sediment overlying the materials producing the anomaly will be done, which should give a reliable deposition date [this was not done because priority was shifted to taking vibracore samples around both *Hunley* and *Housatonic*]. If this anomaly is related to *Hunley* or *Housatonic*, then it may provide a start date for sedimentary deposition on-site and a valuable tool for understanding micro-scale geological dynamics in Charleston Harbor, which have affected both principal site components. Following archeological investigation, documentation and evaluation, the site will be backfilled with local sediments. If it can be determined that the Third Anomaly is unrelated to either *Hunley* or *Housatonic*, archeological investigation will immediately switch to *Housatonic*.

Fourth Anomaly

If time allows, the Fourth Anomaly will be relocated and excavated. The object will be archeologically investigated, drawn and photographed [photography was not possible due to poor water conditions]. Sedimentary samples will be taken from around the site to provide data concerning burial history and other site formation processes.

SITE FORMATION PROCESSES

After sinking, *Housatonic* apparently decayed rapidly and was salvaged in 1864–1865 and again in 1873–1874. In 1909, as part of the Army Corps of Engineers Charleston Harbor improvement, the wreck was dynamited and lowered to remove it as a navigation hazard. It is possible that disarticulated sections of dynamited *Housatonic* boilers or other metallic structures might have been moved by salvors away from the wreck. If so, the Third and/or Fourth Anomalies might be the results of these processes. The 1996 *Hunley* Assessment results indicated that the submarine was in a good state of preservation and that the emergency drop keel was still attached, although the hull bottom was not completely examined. Consequently, there is a possibility that either anomaly represents a section of *Hunley*'s drop keel—an eventuality that would be important for an understanding of the sequence of events surrounding the battle. In short, archeological investigation of the two major magnetic anomalies is designed to answer the questions: "Are these items related to *Hunley*, *Housatonic* or neither?," as well as "What can these materials tell us concerning the dynamics surrounding site formation processes for both *Hunley* and *Housatonic*?"

GEOPHYSICAL STUDIES

Introduction

The 1996 *Hunley* Assessment (Murphy 1998) demonstrated the archeological relevance of sediment analysis and sequencing in determining site formation processes for this area. During the 1999 fieldwork, sedimentary samples will be taken from around *Hunley*, *Housatonic* and the Third Anomaly with vibracore sampling equipment. These samples and cores will be important additions to the 1996 investigations, and they are designed to answer additional questions not addressed in the earlier fieldwork. Careful coring work in the vicinity of *Hunley* will allow for shear strength analysis as well as possibly disclosing stratigraphic sedimentary variations indicative of current actions and scour pockets. These scour pockets could contain artifacts from *Hunley* if the hull has been breached in areas not excavated in 1996. Coring operations will be guided by Field Director Dave Conlin who will ensure through direct inspection and use of a metal detector and probe that cores are taken in an area that will not damage *Hunley* and that anchors from the coring vessel are set well clear of the site.

Coring in the vicinity of *Housatonic* and the Third Anomaly should allow dating of depositional sequences for sediment overlying the two sites and provide an archeological and geological comparison between the three sites. This comparative approach should provide detailed sedimentary data about the processes that have affected the entire site since the loss of the vessels.

Cores will be frozen and split, one half retained for future tests and one half analyzed for shear strength, date of deposition (^{210}Pb),

sedimentary characterization, microbiological and point count analysis and geochemistry [geochemical and microbiological analysis was not done on recovered sediments].

Sediment Strength

In addition to an archeological characterization of the anomalies and *Housatonic*, further environmental information will be collected to assist engineers in formulating a recovery plan for *Hunley*. A geophysical characterization of the sedimentary matrix encasing *Hunley* is vital for ascertaining the suitability of different recovery operations, obligating equipment and personnel, and detailing a sequence of actions to ensure minimum risk to the *Hunley* hull. The sediment shear strength is important to determine if *Hunley* can be excavated without installing retaining walls on the trench sides and to understand the strength of the sediment that encases the fragile prop and rudder areas. One recommendation for *Hunley*'s recovery is that the potentially fragile stern section be recovered encased in its sedimentary matrix (Murphy, Lenihan and Amer 1998:120). This will only be possible if the sediment is of sufficient strength to withstand the dynamic stresses that will be encountered during lift and transport. Furthermore, one recovery option involves lifting *Hunley* as an artifact suspended in the sediments that surround it. In this case, *Hunley* would be boxed in and then the entire box and sediments would be raised.

Understanding what sank *Hunley* is predicated on recovering the submarine undamaged because the force of the explosion may have opened seams in the boiler plating. If the seams are open, archeologists need to know that this is the result of blast damage and not a by-product of the recovery operation.

Sediment Dating

Isotopic analysis of vibracore sediments will provide information about deposition sequences and rates for both *Hunley* and *Housatonic* burial. Dating of sediments over *Hunley* by ^{210}Pb in 1996 indicated that the submarine was rapidly buried, probably within 20–25 years, and it was not subsequently uncovered until its discovery. Dating of cores by ^{210}Pb and ^{137}Cs will provide additional data with which to test conclusions reached following the 1996 assessment and also allow for a comparison between sedimentation rates on the two major components of the engagement site, *Hunley* and *Housatonic* [there were insufficient fine particles in the recovered samples to do ^{137}Cs dating].

Burial Sequence Characterization

Another important research goal for this fieldwork involves characterizing the sedimentary environments surrounding *Hunley* and *Housatonic* in terms of depositional rates and sequence. The 1996 research produced multiple lines of biological and geological evidence pertaining to the rate and nature of *Hunley*'s burial. Similar work done for *Housatonic* will help scientists understand the nature of forces at play on the battlefield site that will assist archeological interpretation of documented and recovered elements. In short, a deeper understanding of how materials are both moved around and buried will assist archeological inferences about the *Hunley/Housatonic* engagement and how to reliably predict the research potential for future investigations.

Remote Sensing

High resolution sub-bottom profiler work in the immediate areas of the two vessels should

reveal sedimentary deposition and possibly the micro stratigraphy in the areas immediately surrounding *Hunley* and *Housatonic*. Differential reflectivity of strata may be able to disclose scour pockets around the wrecks likely to contain artifacts from the battle—information vital to developing a comprehensive recovery plan and to understanding site formation processes. In this case, high-resolution sub-bottom work coupled with sedimentary analysis of the vibracores will point towards further directions for research and special consideration during recovery operations. On the *Housatonic* site, sub-bottom work should be helpful in establishing the nature and extent of the hull remains as well as the presence of nonmagnetic, disarticulated elements not disclosed by the 1996 remote magnetometer survey. Duplicative RoxAnn and side scan sonar survey will allow comparison between 1996 and this season, which will provide data for a longitudinal characterization of sedimentary dynamics at a micro-scale [RoxAnn instruments were not available during the field season].

Remote sensing operations will cover the same area surveyed during 1996 to ensure comparable and duplicative data sets [problems with the Hypack survey software and GPS positioning made this impossible].

ADDITIONAL ENVIRONMENTAL INFORMATION

Further environmental information concerning current strength and direction is also an important element in formulating a safe and effective recovery plan for *Hunley* as well as for understanding the processes that have affected current flow and burial dynamics for materials in the *H.L. Hunley/USS Housatonic* Naval Engagement Site. Information concerning

water clarity, pH, dissolved oxygen and other physical characteristics will be collected during the course of the project [this was not possible due to lack of access to test instrumentation].

PRODUCTS

REPORT

Responsibility for the final written report rests with the project principals and will involve the integration of information contributed by scientists and professionals involved with the project.

GIS

Most project data will be in electronic form and will be added to the 1996 GIS data set to produce a more complete, multidisciplinary understanding of the *H.L. Hunley/USS Housatonic* Naval Engagement Site. This data set will be delivered in archival quality and is intended to serve as a cumulative baseline for further research.

NATIONAL REGISTER NOMINATION

If the *H.L. Hunley/USS Housatonic* Naval Engagement Site displays characteristics consistent with the National Register of Historic Places it will be nominated for inclusion. Responsibility for nomination will rest with the NHC.

PROJECT PERSONNEL AND RESPONSIBILITIES

Co-principal Investigator: Dr. Robert Neyland, *Hunley* Commission, Naval Historical Center—overall strategic decisions, press liaison, project management.

Co-principal Investigator: Christopher Amer, South Carolina Institute of Archaeology and Anthropology—overall strategic decisions, press liaison, project management.

Field Director: Dr. David Conlin, Submerged Resources Center, National Park Service—daily operations, diving operations, team and task scheduling, field documentation.

Assistant Field Director: Jim Spirek, South Carolina Institute of Archaeology and Anthropology—remote sensing operations, daily operations, dive scheduling in the absence of Dave Conlin.

Dive Officer: Carl Naylor, South Carolina Institute of Archaeology and Anthropology—primarily responsible for dive safety, monitoring and tracking dive times, dive protocols.

Conservator: Claire Peachey, Naval Historical Center—artifact stabilization and conservation.

Video/Cameraman: Brett Seymour, Submerged Resources Center, National Park Service—underwater photo and video documentation, surface still photography.

Video documentation of surface work: Tom Posey and Steve Yance, South Carolina Educational TV.

DIVING

Dive safety and accident management will conform to RM-4, the National Park Service's diving practices and regulations. A copy of RM-4 and associated Project Safe Practices Manual will be on the project boat at all times. All diving operations will include a prewritten safety/accident plan. All diving vessels will carry emergency oxygen, dive flags and functional communications equipment [during six weeks of work, there were no diving accidents or incidents].

CHAPTER 4

Field Operations

David L. Conlin, Dana Weise and Nancy T. DeWitt

The USS *Housatonic* Site Assessment began May 22, 1999, and lasted approximately six weeks. This interdisciplinary, interagency field project collected direct observations and remote sensing data concerning the sedimentary environment throughout the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site; identified magnetic anomalies located during the 1996 *H.L. Hunley* Site Assessment; mapped and identified *Housatonic* structural remains; and recovered artifacts associated with the *Hunley*/*Housatonic* engagement (Figure 4.1). A jet probe was used to test 321 positions along transects across the *Housatonic* wreck site (Figure 4.2). Nine 20-ft. (6 m) long sediment cores were collected with a vibracore from representative site areas. In addition, 104 artifacts and samples were recovered (Appendix A). Field operations included personnel from the National Park Service Submerged Resources Center (NPS-SRC), Naval Historical Center Underwater Archeology Branch (NHC), South Carolina Institute of Archaeology and Anthropology (SCIAA), Coastal Carolina

University and Charleston US Geological Survey (USGS).

PREDISTURBANCE INVESTIGATIONS

CORING

On May 23 and 24, the 50-ft. (15.2 m) USGS research vessel *G.K. Gilbert* was rigged at Toller's Cove Marina for remote sensing and vibracoring operations. Field operations began May 25 when three vibracores were taken from around the *Housatonic* wreck.

Vibracoring obtains sediment samples by mechanically vibrating a weighted aluminum core barrel into the sediment. This coring method is superior to other geological sampling methods deployed from small boats because core depths recovered exceed most gravity-driven drop corers. Three-in. (7.6 cm) core diameters of up to 20 ft. (6 m) depth can be recovered, and vibracoring is easier and less equipment intensive than rotary-drill core devices.

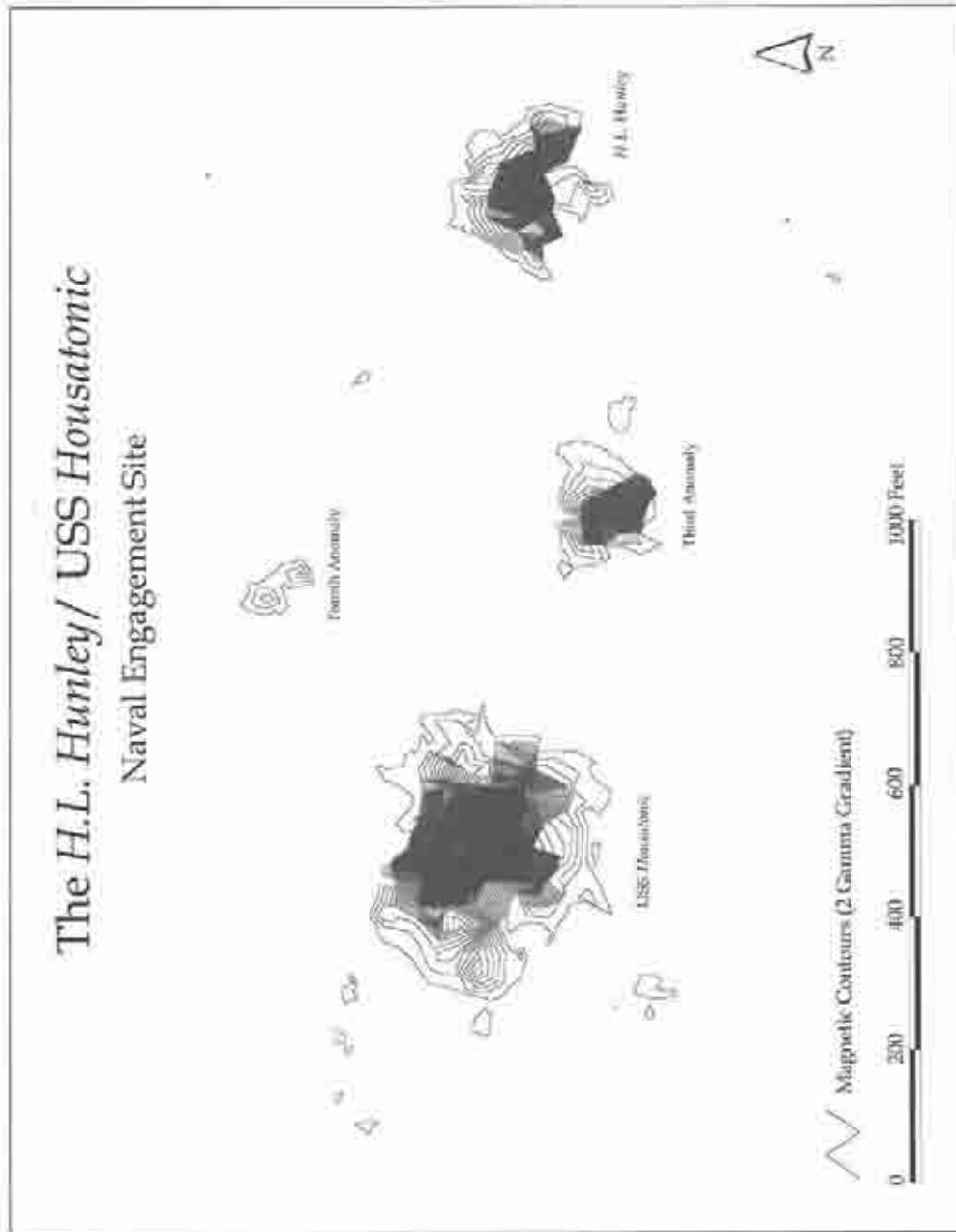


Figure 4.1. H.L. Hunley/ USS Housatonic Naval Engagement Site.

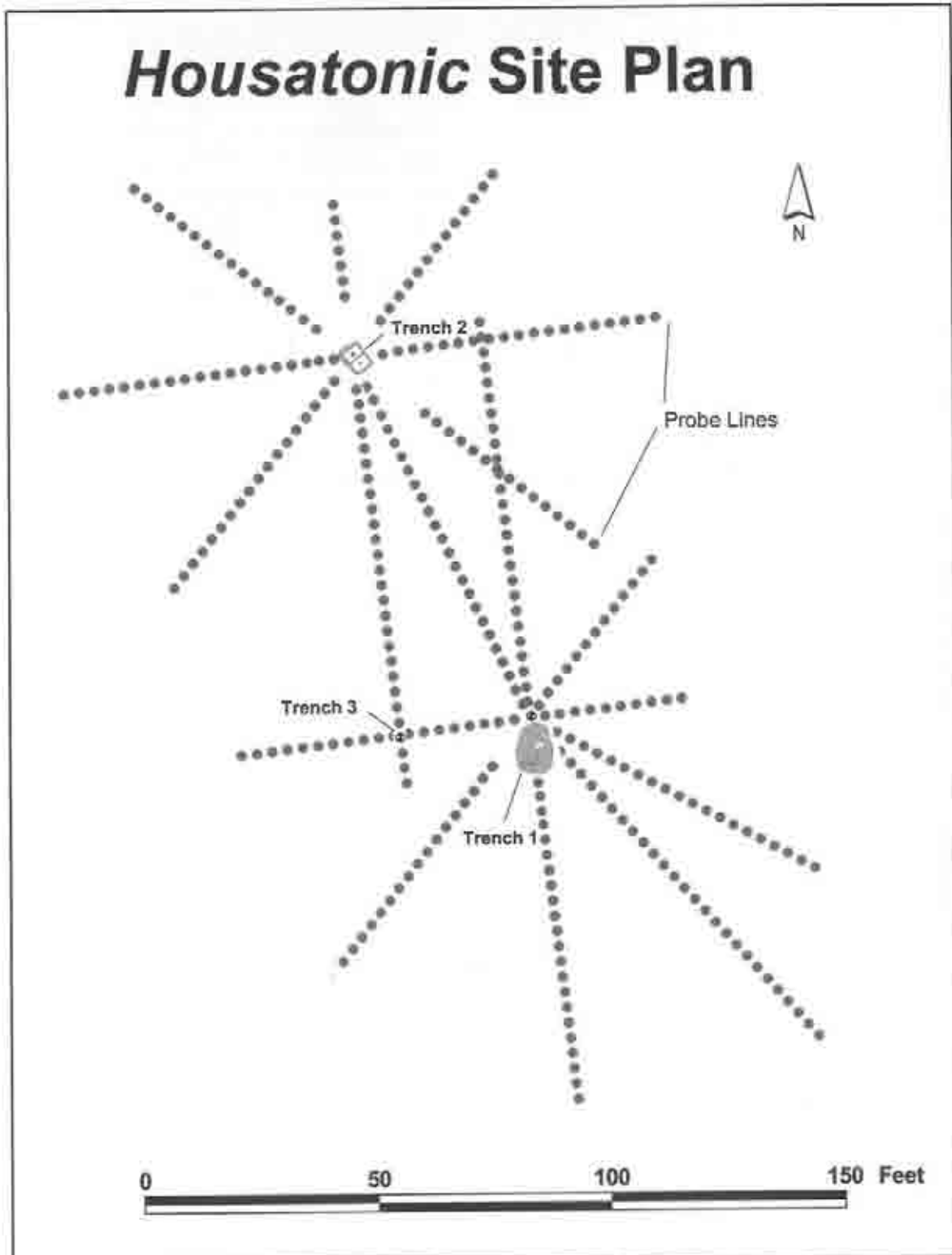


Figure 4.2. Housatonic probe and test excavation locations.

Vibracore sediment penetration, as with all coring devices, is dependent on bottom composition. Pure sands tend to attenuate barrel vibration, which slows penetration; whereas, rock or other hard layers will stop descent of the barrel altogether. Mechanical vibration necessary for core barrel penetration can transmit to the sediment within the core barrel and can compact or disrupt strata of some sediments depending upon their geophysical characteristics. Sediment disruption was a concern for the *Hunley/Housatonic* cores, so the largest possible diameter core barrel (3 in. [7.6 cm]) was chosen to ensure that the center section of the cores would be subjected to minimal vibration impact during the sampling process.

Vibracoring equipment used from the deck of *Gilbert* to collect sediment cores during the fieldwork consisted of a custom-built stabilizing frame containing a 20-ft. (6 m) long section of 3-in. (7.6 cm) diameter aluminum irrigation pipe

oriented perpendicular to the bottom (Figure 4.3). Riveted into the bottom of the irrigation pipe core barrel was a brass sediment catcher. The entire frame and pipe was hoisted off the deck and lowered to the bottom. Once on the bottom, a Bradford pneumatic vibrator coupled to the top of the irrigation pipe was activated by two air compressors delivering 35 surface cubic ft. per minute (scfm) at 100 pounds per sq. in. (psi). As the pneumatic head vibrated, the core was driven into the sediment. The sediment catcher on the core barrel bottom retained the sediment. Once full penetration was achieved, a Hiab hydraulic crane lifted the core and frame assembly aboard *Gilbert*. Core barrel penetration depth and rate were measured using a potentiometer (which measures electrical current) attached to a thin wire connected to the vibracore head. As the core penetrated into the sediment, the wire unrolled off a spool, and the electrical resistance measured by the potentiometer increased. Changes in the



Figure 4.3. USGS research vessel *G.K. Gilbert* deploying the vibracore rig. South Carolina Institute of Archaeology and Anthropology (SCIAA) photo by Chris Amer.

resistance of the wire corresponded to changes in core barrel penetration depth. The rate of change in resistance corresponds to the rate of core penetration, and core penetration rate directly reflects changes in the physical characteristics of the sediments being sampled. Upon recovery, the barrel was removed from the rig and cut to the contained sediment length. The barrel ends were capped, and the core length measured. The measured length was compared to the potentiometer reading to estimate the amount of sediment compaction resulting from core vibration. Accounting for stratigraphic compaction is necessary for accurate stratigraphic interpretation of the sampled sediments.

Positions for the three cores taken around the *Housatonic* wreck were selected by examining remote sensing data collected during the 1996 *Hunley* assessment (Murphy 1998:59–62). Multiple data sets produced in 1996 were combined into a single ArcView Geographic Information System (GIS) project, which allowed for visual analysis and rapid, precise generation of positions for optimal vibracore sampling in 1999. Magnetic contours on 2-gamma intervals from 1996 data were used to select core sample positions likely to be close to *Housatonic* remains with minimum possibility of impacting them. Core sample positions around *Housatonic* are presented in Figure 4.4.

In-water positioning for vibracore sampling was done using *Gilbert's* Trimble differential Global Positioning System (DGPS) navigation unit. The offset from *Gilbert's* GPS antenna to the core barrel in the assembly was measured by tape and direction determined with hand-held compass. Offset calculations were used to correct GPS readings to provide an accurate core sample location.

The compass used for all *Housatonic* assessment measurements was a Sunnto plastic, liquid-dampened, hand-held orienteering compass. This compass is generally employed

for mountaineering and backpacking, but has produced excellent results when used both on the surface and underwater. It can provide approximately 2-degree accuracy on orientation measurements when used under optimal conditions with multiple readings averaged.

Unexpectedly slow coring May 25 and increasingly inclement weather prompted a revision of collection methods so they could be done more quickly. *Gilbert* could be accurately positioned over the desired core sample position, but the required vessel maneuvering slowed the coring process considerably. Consequently, coring operations around *Hunley* involved marking each end of the submarine with buoys and then navigating visually to take a core close to the submarine while avoiding the danger of hitting the wreck (Figure 4.5). Once in place, the core sample position was determined using the same system of DGPS position and offsets as before.

Over the course of two days, nine cores were taken—three from around *Housatonic* and six from around *Hunley*. The *Housatonic* cores were labeled: Hous-1, Hous-2 and Hous-3. The *Hunley* cores were labeled: HUPB (*Hunley* port bow); HUSB (*Hunley* starboard bow); HUPS (*Hunley* port stern); and HUSS (*Hunley* starboard stern). At the starboard bow and port stern locations, two cores were taken in proximity, and these cores were further numbered as HUSB 1A and 1B on the starboard bow and HUPS 2A and 2B on the port stern. Altogether, six cores were taken from around *Hunley*: HUPB 1A, HUSB 1A, HUSB 1B, HUPS 2A, HUPS 2B and HUSS 1A.

All cores were distributed for analysis according to which section of the research design they were to address. HUSB 1A, HUPS 2A and HUPB 1A were transferred to Soil Consultants Inc., a local soils testing company, for structural analysis and geotechnical sediment description. The three *Housatonic* cores, along with HUSB 1B and HUPS 2B, were transferred to the USGS's

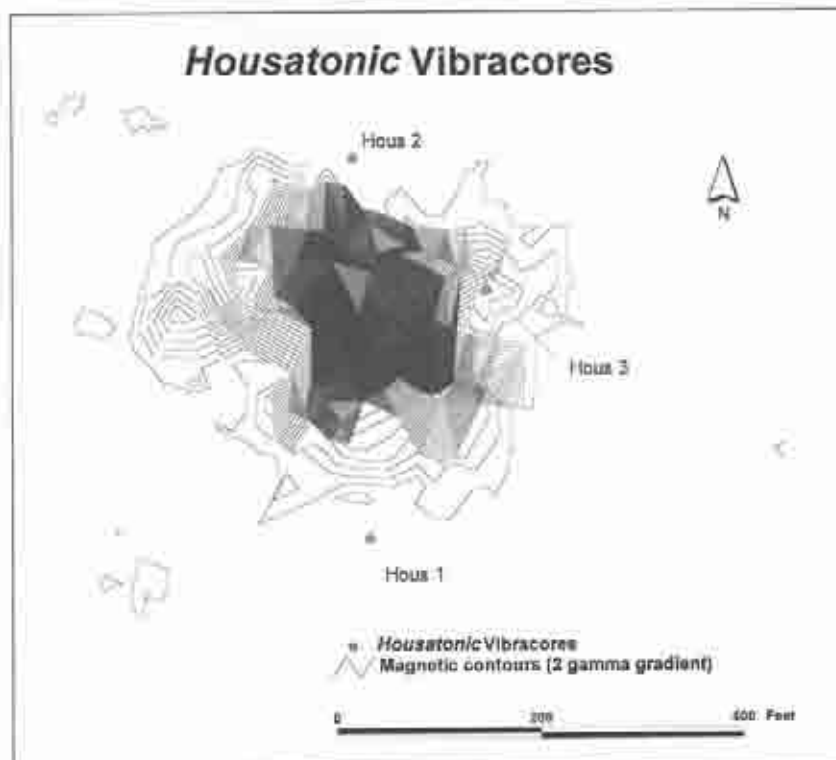


Figure 4.4. Housatonic vibracore locations.

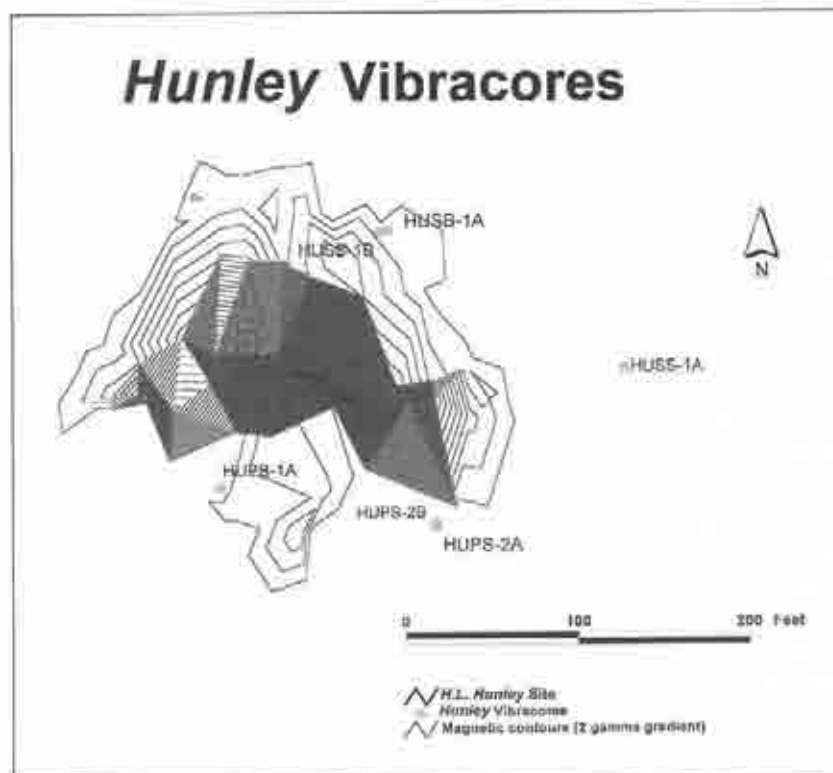


Figure 4.5. Hunley vibracore locations.

Center for Coastal Geology in St. Petersburg, Florida, for lead (^{210}Pb) and cesium (^{137}Cs) chronometric analysis as well as sedimentary characterization. Once in St. Petersburg, the USGS vibracores were split longitudinally with a circular saw and visually described for lithology, sediment type, texture, shell content and stratigraphy. One half of each of these vibracores was kept intact for photography; the other half was subsampled for lead and cesium radiometric dating. The sixth core, HUSS 1A, taken near *Hunley's* starboard stern, has been preserved under refrigeration by the Charleston Museum for possible future analysis.

REMOTE SENSING

On May 27, *Gilbert* was rerigged for geological remote sensing operations to collect seismic and sonar data using two sub-bottom profilers and a side scan sonar. Difficulty integrating *Gilbert's* DGPS unit with Hypack hydrographic software prevented repeating the precise survey transects used in the 1996 survey, as originally planned to allow direct data comparison. Instead, project leaders marked the two wrecks with buoys and visually navigated by crisscrossing the area around both sites while towing the sensor arrays. This method generated thorough coverage and a large quantity of data over and near both *Housatonic* and *Hunley* and all vibracore collection locations.

Remote sensing deployed three different sensor arrays: seismic sub-bottom; CHIRP high-resolution sub-bottom; and side scan sonar, all linked together with P-code (military grade) GPS positioning, which provides a 3–5 m (9.8–16.3 ft.) circle-of-error.

Seismic Reflection Data

Sub-Bottom Profiler

An Applied Acoustic AA200 sub-bottom profiler system was used to collect seismic

reflectivity data. This instrument employs an electromechanical “boomer” plate triggered every 250 milliseconds by a CSP 300 power supply, which was maintained at 100 Joules with a 250-millisecond shot rate and a 50-millisecond sample period. The hydrophone array was towed off *Gilbert's* starboard side and the boomer plate off the port. Navigation data were provided by a Rockwell Precision Lightweight GPS Receiver (PLGR) P-code GPS receiver at a rate of 1 fix per 2 seconds.

The boomer energy pulse reflects off sub-bottom sedimentary features and is received by an Innovative Transducers ST5, 10-element, solid hydrophone. A Kontron portable PC equipped with an analog-to-digital signal processor card and other interface devices processed the ST5 signal; acquisition and processing software was Triton Elics Delph Seismic software running under Windows 95. The data were archived onto hard disk, and a paper copy was generated for field processing and analysis.

CHIRP Sub-Bottom Profiler

CHIRP high-resolution, shallow sub-bottom profiler data were collected with an EdgeTech Geo-Star FSSB system and an EdgeTech SB-424 towfish containing a computer-generated, wide-band sound source and hydrophone. Data were acquired, processed, archived and displayed on the GeoStar system. The SB-424 towfish collected data in a frequency range from 4–24 kHz in increments of 4–16 kHz, 4–20 kHz and 4–24 kHz. The SB-424 was towed off *Gilbert's* starboard side at a depth ranging from 3–6 ft. (.9–1.8 m). Navigation was provided by a Trimble Centurion P-code GPS receiver at a rate of 1 fix per 60 seconds. All navigation data were displayed and logged by the GeoStar system.

Both the CHIRP and Applied Acoustic sub-bottom units characterize underlying geological

structures and are complementary in their different ranges and resolutions. The sub-bottom profiler characterizes deeper strata at a lower resolution, and the CHIRP depicts shallow strata, which are of primary archeological interest, in high resolution. Both instrument's data combined provide a comprehensive depiction of seabed strata that can be correlated with the strata collected in the cores. This correlation of core strata and reflectors allows for very accurate stratigraphic interpretation from sub-bottom data and allows results of core strata analysis to be projected reliably over a large area.

Side Scan Sonar

Side scan sonar data were collected over both sites. An EdgeTech 272 TD Dual Frequency towfish, SeaMap Sonarlink interface and a Kontron portable PC equipped with an analog-to-digital signal processor card and other interface devices were used for sonar data collection. Acquisition and processing software was Triton Elics Isis running under Windows 95. Data were archived onto hard disk and a paper copy was generated for later processing and analysis. Swath widths were 50 m per side (port/starboard). Side scan acquisition frequencies were 100 kHz and 500 kHz. The side scan sensor was towed off the bow at a depth ranging between 1 and 2 m. Navigation was provided by a Rockwell PLGR P code GPS receiver at a rate of 1 fix per 2 seconds. All navigation was displayed and logged by the Triton Elics system.

NAVIGATION

Survey tracklines and positioning were acquired, displayed and archived using a USGS Amrel Rocky laptop PC running USGS 'Fugawi' mapping software under Windows 95.

Navigational data were supplied concurrently to both the seismic and sonar systems. Multiple survey lines were run to thoroughly cover the study areas. Seismic, sonar and CHIRP data were collected simultaneously on each trackline. Data collection points and tracklines for the geological remote sensing phase of the project are depicted in Figures 4.6 and 4.7.

GENERAL DIVING OPERATIONS

Two dives were completed May 25 to check *Hunley's* location prior to vibracore collection. Archeological diving operations began June 8, 1999 and continued until July 14. Over the course of 41 days, 10 days were lost to weather and 5 days to equipment failure or other causes. A total of 26 days were spent diving, and during that time, 257 dives were safely made by the team in extremely challenging conditions that included low visibility, high current and marginal sea state (Figure 4.8).

Positioning for dive locations was by a military-grade Rockwell PLGR P-code GPS receiver. Once an excavation site was located with the PLGR, it was marked with a small buoy that facilitated reacquisition on subsequent days. The buoy was small enough that it could not be easily seen unless one knew where to look, but large enough to discern from a distance of approximately 100 ft. (30.5 m). Unlike the 1996 *Hunley* fieldwork, the team did not deem it necessary to pull the buoy every day at the end of work for site security.

Divers entered and exited the water from SCIAA's dive boat *C-Hawk*, with the majority of the excavation team waiting for their turn to dive on the South Carolina Department of Natural Resources' vessel *R/V Anita* anchored close by. *C-Hawk* was anchored at the bow and stern on a two-point moor over the dive site, and personnel transferred from *Anita* via inflatable. This procedure allowed a large team

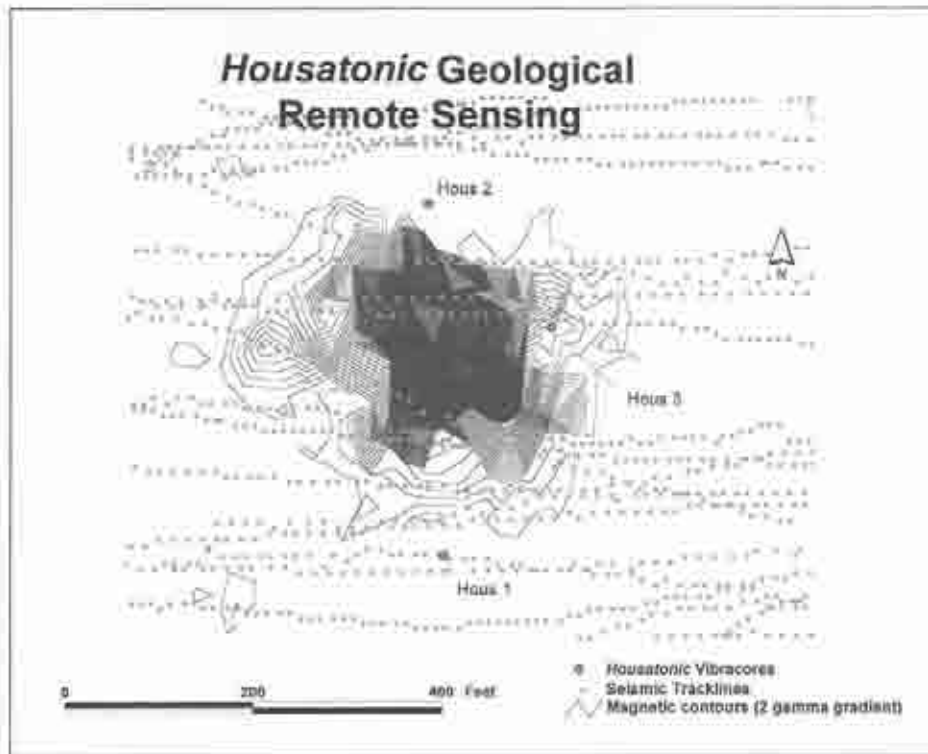


Figure 4.6. *Housatonic* data collection points.

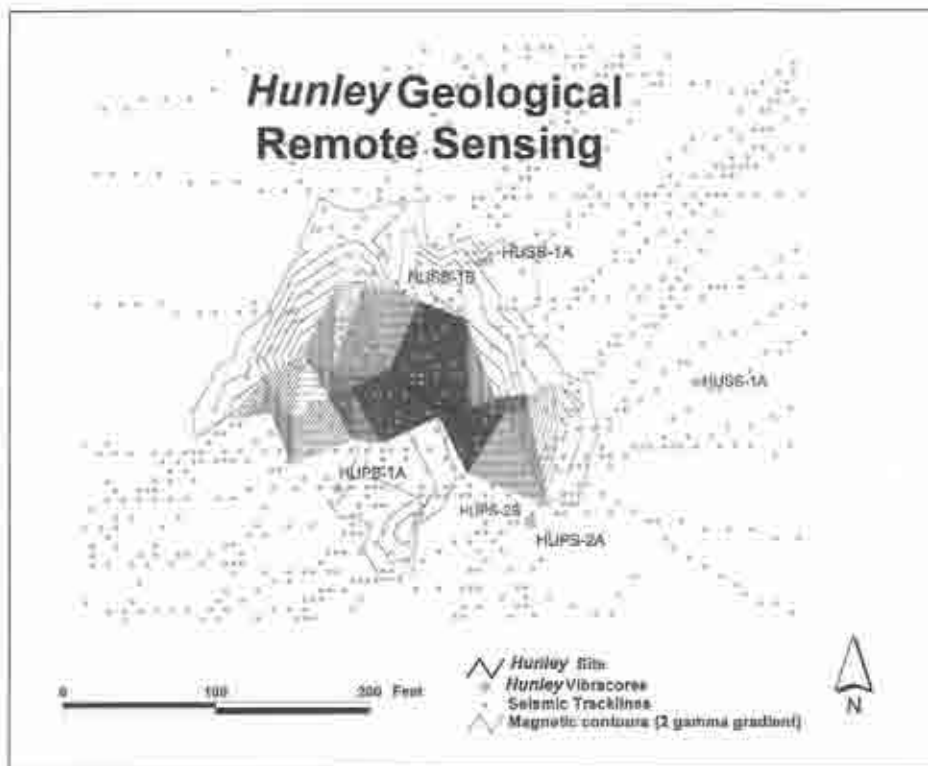


Figure 4.7. *Hunley* data collection points.

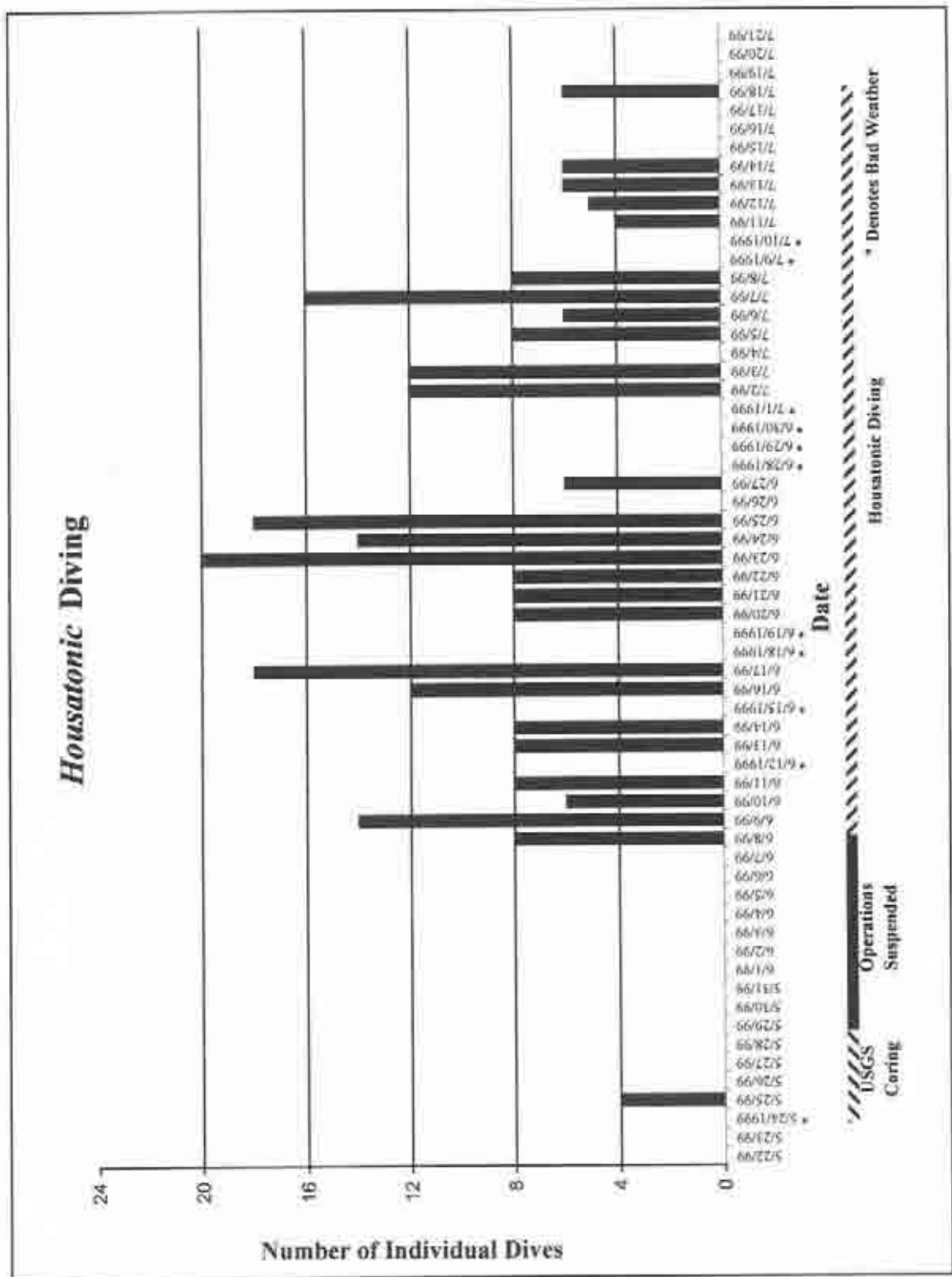


Figure 4.8. Housatonic diving operations.

to work on the site in shifts and avoided damage to either of the two vessels that would have resulted from rafting them together in the frequently rough seas. Team members not diving were able to complete project related paperwork in *Anita's* relatively spacious cabin, and *C-Hawk's* low free board made it possible to utilize small gasoline water pumps to power the 4-in. (10.1 cm) induction dredges used for excavation (Figure 4.9).

Due to suspended sediment, diving conditions were difficult to extreme with zero visibility the norm in excavation areas and less than 1 ft. (.3 m) visibility, occasionally extending to 2 ft. (.6 m), outside of them. These conditions hampered productivity and made photographic documentation of site features impossible. In addition to low visibility, currents were strong and occasionally forced suspension of diving operations. Weather during the *Housatonic* assessment was unsettled, and sea states made diving impractical on several occasions. Safety lines were used at all times to guide archeologists

from *C-Hawk* to the bottom and from one area of the site to another.

Excavation surrounding archeological features was accomplished using a 4-in. (10.1 cm) induction dredge coupled to a 2-in. (5 cm) fire hose that ran from a gasoline pump onboard *C-Hawk*. The 4-in. (10.1 cm) dredge had enough power to move overburden from the excavation area, but not so much that it was uncontrollable by a single diver. Dredge spoil was moved laterally from the excavation area and deposited on the seafloor outside of the excavation area. Periodically during the excavation, the dredge outflow would be moved, and at that time the spoil pile examined for artifacts that had been inadvertently drawn up the dredge.

Archeologists collecting data for the *Housatonic* assessment relied heavily on a jet robe. The jet probe, constructed specifically for this fieldwork, consisted of an 8-ft. (2.5 m) section of 1½-in. (3.8 cm) galvanized steel pipe connected to a 2-in. (5 cm) fire hose with a T-



Figure 4.9. Diving operations underway off *C-Hawk*. SCIAA photo by Chris Amer.

fitting, which was coupled to a water pump on *C-Hawk*. Water pressure through the pipe was regulated by means of a ball valve atop the pipe. By opening and closing the ball valve, archeologists could regulate the pressure flowing out of the bottom and top of the steel pipe. The pipe was marked with ridges of tape at 1-ft. (.3 m) intervals, which allowed quick determination of pipe depth in the sediment, even in zero visibility. When the probe hit something, listening to the sound the pipe made while hitting the object gave the operator an idea of what the material was—metal made the pipe ring, wood produced a dull “thunk” and coal produced a characteristic scratching sound.

In addition to the jet probe, a J. W. Fisher Pulse 8x underwater metal detector was used to locate small, shallow buried metal materials. With the exception of the work done at the very outset of the project, all materials documented during the *Housatonic* assessment were buried too deeply in the sediment to be found with the metal detector.

A Quantro Sensing Discovery hand-held underwater proton magnetometer was used during test excavation to locate larger ferrous objects beyond the detection range of the metal detector. The Discovery magnetometer is a full-field proton magnetometer that provides data in the form of absolute magnetic field readout. The unit measures the magnetic field that surrounds the sensor head and displays magnetic readings in a numeric form visible underwater. The magnetometer senses local disturbances in the earth’s magnetic field, or anomalies, caused by ferrous material. In the case of an area like the *Hunley/Housatonic* Site, these anomalies corresponded to archeological materials buried in the sediment.

All measurements done on the *Housatonic* Assessment were done in feet and inches—this was to ensure compatibility with work done in feet and inches during the *Hunley* Assessment

in 1996 and to correlate with the system of measurement in which *Housatonic* was originally built in 1862. Two exceptions to this were the spacing of the probe holes, which were done in accordance with the transect line that was already knotted in 1-m (3.3 ft.) increments when the project started and diameter measurements on the Third Anomaly that were done in centimeters for ease of calculation purposes.

TEST EXCAVATIONS

STRATEGY

The excavation strategy for the *Housatonic* Assessment directly reflects the project research design (Chapter 3). Primary excavation objectives were: 1) locating and evaluating the outlying anomalies and determining their potential association with other elements of the *Hunley-Housatonic* engagement (Figure 4.1); 2) delineating the structure and assessing the state of preservation of *Housatonic*; 3) determining the orientation of *Housatonic*’s hull; 4) assessing the density, type and preservation state of artifacts on *Housatonic* and recovering some artifacts to assist in site interpretation; 5) documenting site formation processes including salvage activities, obstruction clearing and burial processes; and 6) if possible, documenting evidence of the *Hunley* attack on *Housatonic*.

Adhering to the minimum impact investigation strategy of the 1996 *Hunley* assessment, only small test excavations were conducted. Test excavation locations were initially determined by examining remote sensing data derived from the 1996 survey. The initial test excavation locations were refined using the jet probe to delineate wreck areas not deeply buried. In the case of the *Housatonic* site, probing proved invaluable because the site produced magnetic gradients

of up to 1,000 gammas over a distance of less than 20 ft. (6 m). These steep gradients made effective use of the hand-held, in-water magnetometer impossible in some areas. In areas of less gradient, the hand-held magnetometer was utilized to locate the test excavation over a ferrous target.

Once a test excavation area was located, the overlying sediment was removed until features were distinguishable, or, if nothing was located, until it became clear that continued excavation would prove unproductive. Systematic probing and use of the magnetometer, concurrent with excavation, pointed to promising areas for new test excavations.

As data indicating the orientation of the wreck beneath the sediment were collected, excavation activities were redirected to the stern area that might show evidence of the attack and or postdepositional processes such as salvage and obstruction clearing. Primary areas of interest were the boilers and engine, the starboard stern quarter, and the propeller and propeller shaft assembly. Historical accounts report that both the starboard stern quarter and the propeller area were damaged in the attack, and once the layout of the wreck was determined and postdepositional processes understood, the ultimate goal was to document the effects of the attack.

TEST EXCAVATIONS

The test excavation phase of the *Housatonic* Assessment began on June 8 with an examination of the magnetic anomaly lying between *Housatonic* and *Hunley* referred to as the "Third Anomaly," (Figure 4.1). A location to begin this examination was selected by evaluating the 1996 2-gamma anomaly contours. This data set had been incorporated into the *Hunley-Housatonic* ArcView GIS project, and it was a simple matter to select the desired location, record its coordinates from the GIS, load them into the

PLGR and navigate to the position on site. A buoy was thrown on the selected position, and diving operations began to systematically search for cultural features above the seabed.

The object producing the anomaly protruded from the bottom approximately 10 in. (.25 m) and was rapidly acquired on the morning of June 8 by Brett Seymour and Jim Spirek. Throughout June 8–9, archeologists excavated the anomaly to the point that it could be examined. Based on presence of several worm rock colonies attached to the object, amount of corrosion, degree of burial, and its proximity to *Housatonic*, project archeologists determined it historic and likely associated with other materials of the *H.L. Hunley/USS Housatonic* Naval Engagement Site.

On June 9, multiple lengths of 4 mm braided stainless steel wire, a section of 3/8 in. (.9 cm) polypropylene rope and a weight made from a lead-filled copper tube were found attached to the object. Though the Third Anomaly was not completely excavated, it appeared that the wire and rope were wrapped all the way around it, with the dive weight strung on the lines. Three large colonies of worm rock had grown over and around the polypropylene rope and wire. Because of the potential they had for contributing to understanding the burial dynamics on the *Hunley/Housatonic* site, sections of the rope, the dive weight and one of the colonies of worm rock were recovered for evaluation, documentation and analysis (Appendix B).

The diameter of the Third Anomaly was measured June 9. Because the object appeared to be quite large, and it was buried almost completely, the diameter was measured indirectly. A standard measuring tape was attached to the exact center of a section of a 114-cm (3.8 ft.) long metal pipe. While on the bottom, each end of the pipe was set so that it just touched the outer, curving edge of the Third Anomaly (Figure 4.10). The tape was pulled

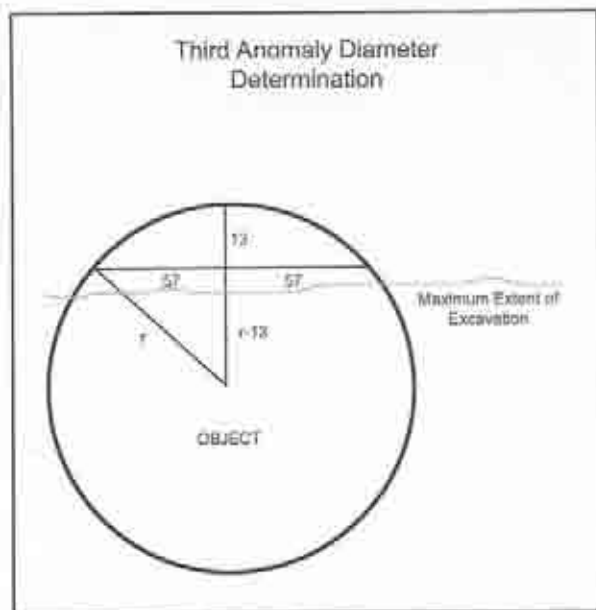


Figure 4.10. Determination of the Third Anomaly diameter.

tight to the edge of the Third Anomaly and moved back and forth until it measured the shortest distance from the center of the pipe to the edge. At this point the tape was perpendicular to the pipe and an imaginary line drawn through where the tape touched the edge of the Third Anomaly to the center of the pipe would continue on to intersect the geometric center of the round end of the Third Anomaly. The distance measured was 13 cm (5.1 in.), so we had the measurements of two sides of a right angle triangle with the third (hypotenuse) unknown but corresponding to the radius of the Third Anomaly. With one side of the triangle measured at half of 114 cm (57 cm [1.8 ft.]) and the other measured at the radius of the buoy minus 13 cm ($r-13$) (5.1 in.) the hypotenuse could be calculated according to the formula:

$$r^2 = A^2 + B^2$$

Adding values for the variables, produced:

$$r^2 = 57^2 + (r-13)^2$$

Solving the quadratic produced

$$r^2 = 3249 + r^2 - 26r + 169$$

$$26r = 3249 + 169$$

$$26r = 3418$$

$$r = 131.46$$

$$\text{Diameter} = 2r = 262.92\text{cm or } 8 \text{ ft. } 7 \frac{1}{2} \text{ in.}$$

Following the brief examination of the Third Anomaly, operations turned to an examination of *Housatonic* on June 10. Based on anecdotal accounts, wreck remains were believed to be protruding from the bottom or be so close to the sediment line that locating them with a circle search and/or a metal detector would be effective. The team began a series of circle searches to locate hull remains above the seabed. Throughout the day, divers swam circle searches both with and without the metal detector on positions derived from examining the 1996 survey data, in the same way as on the Third Anomaly. A combination of zero visibility and the apparently complete burial of the site made systematic circle searches ineffective. With bad weather approaching, operations were terminated early.

On June 11, the team returned to positions taken from the 1996 survey data with a hand-held proton magnetometer. Throughout the day archeologists swam circle searches with the magnetometer with conflicting results and no clear indications of where, exactly, the site lay beneath the sediment. Because the instrument was new, it was not clear if the problem lay with the instrument, with the operator or with something else. Weather again caused fieldwork termination in early afternoon.

After being down for weather on June 12, the team returned to the site on June 13 with the magnetometer and jet probe. During the interval, the hand-held magnetometer was tested and determined to be working to specifications. The methodology was revised and small changes in magnetic intensity were given new importance. A combination of systematic magnetometry with the hand-held instrument and jet-probing produced a solid contact on

unknown materials 6 ft. (1.8 m) below the seabed.

Because this was more overburden than anticipated, project principals believed there must be areas of the wreck not so deeply buried, and they decided not to excavate this 6-ft. (1.8 m) deep area. In addition to the deep site, a test excavation of a hard return located with the probe at 4 ft. (1.3 m) below the seafloor revealed it to be a lens of shell hash, which mimicked a hard return to an inexperienced operator. This further complicated finding buried elements of *Housatonic* until team members gained more experience in distinguishing the different types of probe returns from the false return of shell hash. Finally at the end of the day on June 13, the team probed into materials at about 6 ft. (1.8 m) deep that were much firmer than had been previously encountered that gave off a metallic ring when prodded with the jet probe.

On June 14, the team divided with some engaged in side scan sonar operations aboard *Anita*, and the others continuing excavation of the hard metallic contact encountered the previous day. The side scan sonar was deployed to reexamine the site to determine whether or not there were any remains of *Housatonic* above the seabed. Repeated crossings of the study area with the side scan sonar produced no contacts above the seabed. At this point, it was clear that the entire *Housatonic* wreck was covered by sediment. Radio conversations between *Anita*'s captain, Paul Tucker, and shrimp fishermen working in the area confirmed this to be the case. Local shrimp fishermen reported a single hang for their shrimp nets in the vicinity, which corresponded to the object documented at the Third Anomaly. This independent data supported the assessment drawn from the sonar data that the remains of *Housatonic* are completely buried.

From June 14–23 (with three days down for bad weather), the team excavated what was

designated as "Trench 1" with a standard 4-in. (10.2 cm) induction dredge. Cultural materials in Trench 1 ranged in depth from 5–6 ft. (1.5–1.8 m) below the seabed. Artifacts lay upon a stratum containing coal, and no apparent structural features were encountered. The jumbled nature of the test excavation unit with no articulated structure made interpretation difficult.

On June 24, excavations were moved to a new region of the wreck, located by the now proven combination of probing and hand magnetometry on a location drawn from the 1996 remote sensing data. At a depth of 4 ft. (1.3 m) below the seabed, two square metal tanks were found next to each other in the test excavation. Examination of *Housatonic*'s sister ship, USS *Ossipee*'s plans indicated these tanks were most likely water tanks located in the forward hold. Excavation in what was designated as "Trench 2" continued from June 24 through July 2. Excavations expanded to document the two probable water tanks. Structural contact during systematic jet probing of the area indicated these tanks were on the starboard side in their original position.

On June 27, Dave Conlin was able to take measurements critical to *Housatonic* site interpretation. Two 4-ft. (1.3 m) long metal rods set 3 ft. (.9 m) apart were pounded into the 1-in. (2.5 cm) space that separated the two water tanks excavated in Trench 2. A taut line was strung between the two rods about 3 ft. (.9 m) above the tanks, where visibility approached 6 in. (15.2 cm), and a compass was minimally affected by the magnetic disturbance of the iron tanks. The magnetic orientation of the line between the rods was determined with a hand compass. Four measurements of the line's orientation were taken, with three being averaged and the most disparate measurement discarded. Because these tanks are aligned longitudinally on the plans, the bearing of the



Figure 4.11. Commander David Whall (USN Ret.) prepares for probing operations. SCIAA

line, which is perpendicular to the keel, can, when added to 90 degrees, be interpreted as indicating the orientation of the ship's hull.

While Trench 2 was being excavated and documented, systematic probing of the entire site began starting at a datum established in the center of the northernmost (forward) water tank (Figure 4.11). A 1/8-in. (.3 cm) polypropylene line knotted at 1-m (3.3 ft.) intervals for a length of 50 m (164 ft.) was set on compass bearings of north, northeast, east, southeast, west, southwest, south, southeast, east and northeast from the datum. The knotted line would allow a diver deploying the jet probe in zero visibility

to maintain a 1-m (3.3 ft.) sample interval along the transect line.

Diver orientation during deployment of the transect lines was controlled in one of two ways. If the seas were flat and currents not running, a diver ran the line out to its end while on the bottom and then floated a buoy to the surface from the *C-Hawk*, moored directly over the datum. Using surface to diver communications equipment, an observer on the surface could direct the diver back and forth until the line bore off from *C-Hawk* at the proper compass bearing. If the seas were choppy, or if current was running, divers navigated on the bottom using a hand compass and then checked the line orientation multiple times while on the way back along the line to the datum.

Because only one vessel was being used for diving operations, it was not practical to position the buoy that marked the end of the transect line with GPS. Had that been possible, the exact orientation of the line would have been more closely determined, and this would have increased the accuracy of the probe positions. Transect line orientation contains a level of uncertainty that affects the precision of the inferences based on jet-probe positions and results.

Once the knotted transect line was laid out and secured at both ends, a diver with the jet probe and communications gear would feel along the transect line and probe at each knot. As the probe was pushed into the bottom, the diver noted the probe depth, the distance from the datum represented by number of knots, and whether the probe was hitting metal, wood, coal or nothing. This information was relayed to the surface and transcribed by the communications operator onboard *C-Hawk* where it was recorded (Figure 4.12). At the same time, the surface recorder verified the knot count and, therefore, distance from the datum.



Figure 4.12. Archeologist Claire Peachey probing the *Housatonic* wreck. NPS photo by Dave Conlin.

On July 2, while final documentation of Trench 2 was being completed, the team reacquired the Trench 1 datum and began systematic probing from that location in the same manner as was done on the Trench 2 datum.

While probing was proceeding systematically, another test excavation was begun at what was designated "Trench 3." The location of Trench 3 was determined by a series of 4 ft. (1.3 m) deep metallic probe contacts south of Trench 2 and on the presumed hull orientation derived from the tank measurements. Trench 3 is located 52 ft. (15.8 m) south of the Trench 2 datum. Trench 3 was excavated from July 3 until July 11 with interruptions for poor weather and other issues on July 4, 6, 8, 9 and 10. Altogether, four days were devoted to excavating this area of the site. Only a field sketch of Trench 3 was produced prior to moving on to other areas of the wreck.

Currents and sea conditions on site during the first week in July were extremely difficult

and, in an effort to adapt equipment to challenging seas, the team rerigged *C-Hawk* with a single-point anchor instead of the two-point anchor. The dredge and probe hoses were tied to the anchor line, and this arrangement allowed *C-Hawk* to pivot to face the weather and wind without dragging hoses and equipment out of the divers' hands. This worked well and allowed continued productivity under conditions that were previously unworkable.

On July 11, there were sufficient data about *Housatonic's* orientation and extent that a test excavation could be positioned so as to find a particular site feature based on a prediction derived from a combination of the oriented and scaled ship's plans, the GIS site database and GPS positioning. Evaluation and correlation of these data produced coordinates likely to be close to the ship's propeller and shaft. Location of these features could provide important information regarding hull damage resulting from *Hunley's* attack. After setting a datum at

the selected coordinates, the team began to probe without success. Weather, again, forced an early closure of fieldwork. Probing for the propeller resumed on the morning of June 12 without success, and, with more bad weather looming, the effort was reluctantly abandoned. Despite its lack of success, replication of this methodology for future site examinations could be very productive.

On July 13 and 14, systematic probing was completed on all transects originating at the Trench 1 datum. Trenches 1, 2 and 3 were marked with below-water buoys and metal marker stakes set just below the seafloor to allow for future reacquisition either visually or with a metal detector. This should assist reacquisition and future work.

On the afternoon of July 14, the team completed probing all transects and shifted operations to briefly examine the Fourth Anomaly (Figure 4.1). After a short search using the hand magnetometer and probe, the buried object producing the magnetic anomaly was located approximately 3 ft. (.9 m) below the seafloor. The object was identified as a section of chain. Unfortunately, arriving bad weather precluded complete excavation and recording of the object.

Demobilization for the project commenced July 15 and continued through July 16. On July 18, the team was able to acquire a boat and return to the Fourth Anomaly. Again using a combination of hand magnetometer and probing, the chain was quickly relocated and excavated. Following the chain along its length lead to a small admiralty-type anchor. Following a day of diving and documenting the Fourth Anomaly, project personnel resumed demobilization and the project was finished on July 21.

ARTIFACTS

All recovered artifacts were documented in the field both on artifact forms and on dive logs.

Artifacts were placed in plastic tubs and transported to the team's Folly Beach base of operations where they were drawn, measured and photographed. A number of the metallic artifacts were X-rayed at the Medical University of South Carolina both digitally and on film. All artifacts were conserved in the field by project conservator Claire Peachey prior to being moved to the NHC Conservation Laboratory for further treatment and study. The Field Specimen Catalog is in Appendix A.

CONCLUSION

During the period from May 22 to July 21, sufficient information was recovered from the *H.L. Hunley/USS Housatonic* Naval Engagement Site to enhance understanding of this historic naval encounter. Using instruments of varying degrees of sophistication, the team successfully recovered geological and archeological data and samples pertaining to site formation processes and the Union side of the encounter. A coherent research design for 1999 was developed by drawing upon data and research themes developed in 1996. Field methods derived from this design produced concrete, systematic and comparable data to create a broader understanding of multiple facets of this complex site. A systematic approach guided by a research design grounded in minimum-impact approaches has been demonstrated to work even under severe conditions of very low to no visibility exacerbated by inclement weather. The practical strategy of relying heavily on remote sensing data and other predisturbance techniques prior to excavation is effective and efficient. GIS-based approaches, which allow the development and rapid manipulation of cumulative data sets and quick addition of new data, contributed directly to the success of this work.

CHAPTER 5

Site Description

David L. Conlin

INTRODUCTION

The *H.L. Hunley/USC Housatonic* Naval Engagement Site consists of four principal components: the wreck of the Union blockade ship *USC Housatonic*; the magnetic anomaly designated "Third Anomaly"; another magnetic anomaly designated "Fourth Anomaly"; and the wreck of the Confederate submarine *H.L. Hunley* (Figure 4.1). The *H.L. Hunley* site has been reported elsewhere (Murphy 1998). This chapter describes the other three site components as documented in Chapter 4: Field Operations. Site Analysis is presented in Chapter 9 and Conclusions and Recommendations in Chapter 10. Additional data for the different areas of the site can be found in Appendices A through E.

USS HOUSATONIC

PROBE LINES

Altogether, 321 individual probe holes in 17 different directions spanning more than 1,000

linear ft. (304.8 m) covering an area more than 35,000 sq. ft. (3,251.6 sq m) were completed over and around the *Housatonic* wreck. Of the 321 holes documented during site probing, 43 were coal, 23 wood, 108 metal and 147 did not hit anything (Figures 5.1 and 5.2; Appendix C). The shallowest probe return was 3 ft. (.9 m) below the seabed, and the maximum depth for probe returns was 8 ft. (2.4 m). Materials buried deeper than 8½ ft. (2.6 m) below the seafloor were not detectable by the probe.

TRENCH 1

Trench 1 contained materials buried at a depth of 5–6 ft. (1.5–1.8 m) below the seafloor. The area excavated was an oval hole 10 ft. (1 m) long by 6 ft. (1.8 m) wide (Figures 5.3 and 5.4). The trench bottom was a solid, uneven floor of large pieces of coal, tightly bound together in a sediment matrix. Altogether, 44 artifacts were recovered, including a pistol and other gun parts (Hunhou 99-042, 99-025 and 99-041); five zinc artillery fuses (Hunhou 99-

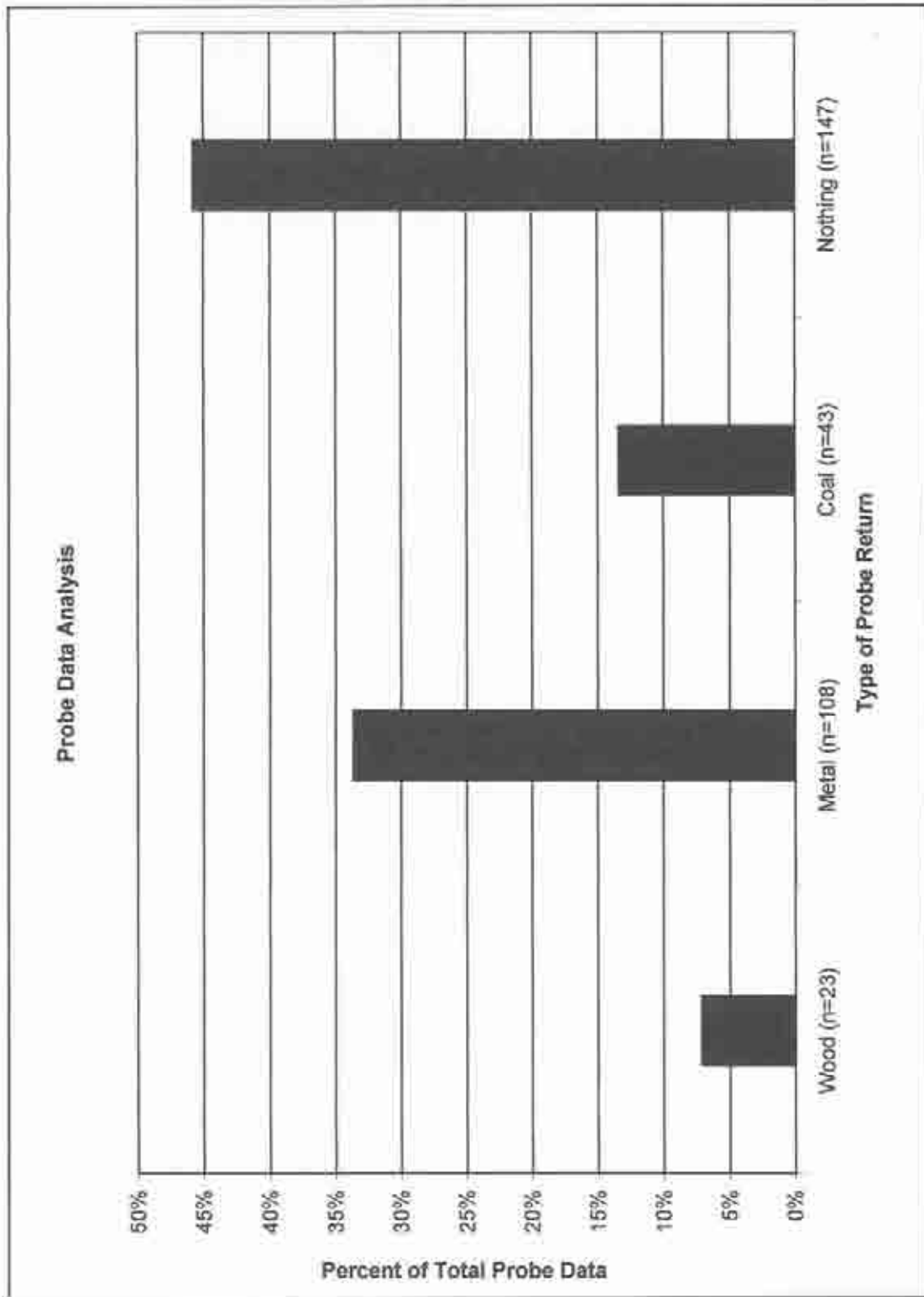


Figure 5.1. Probe hole data.

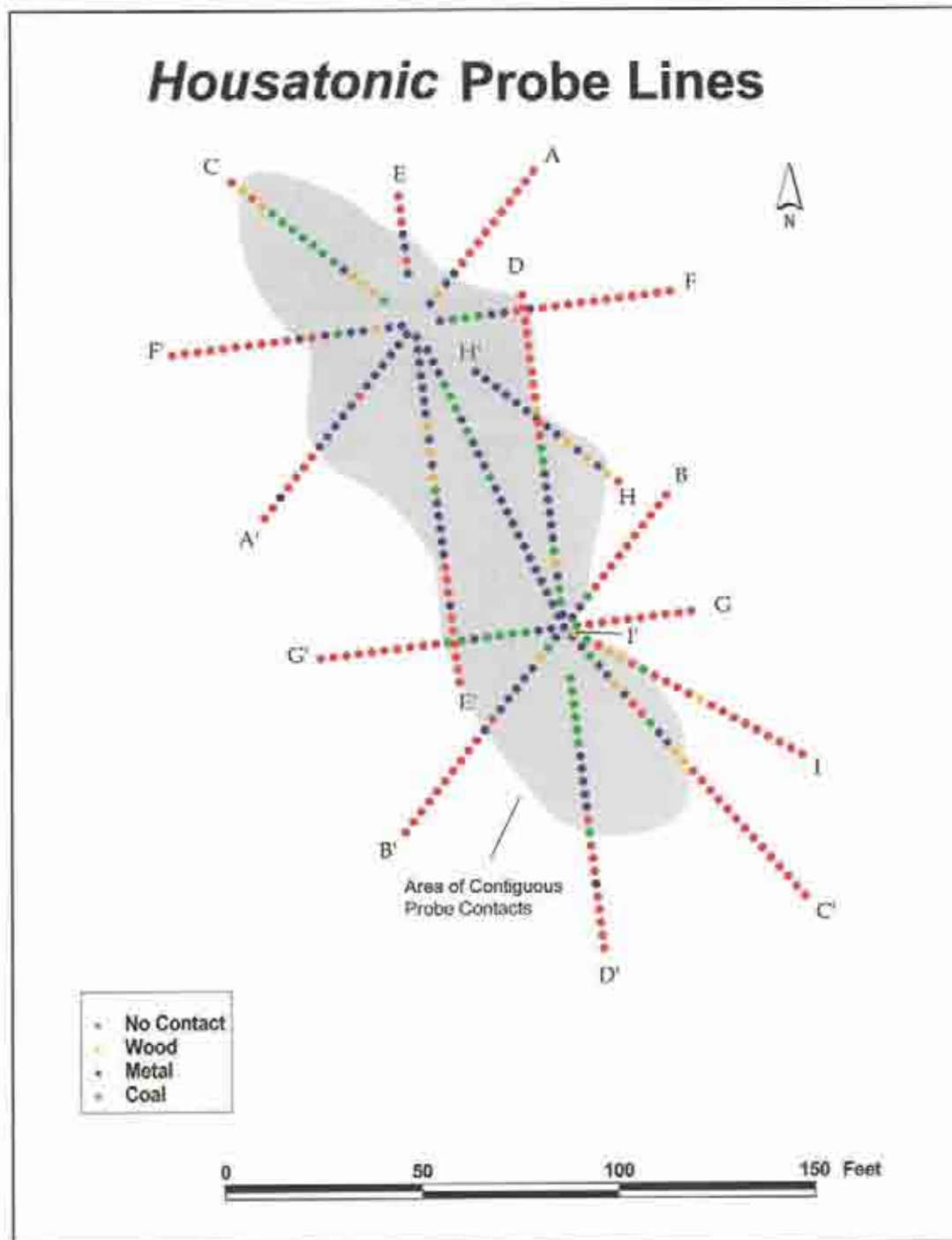


Figure 5.2. Housatonic probe lines.

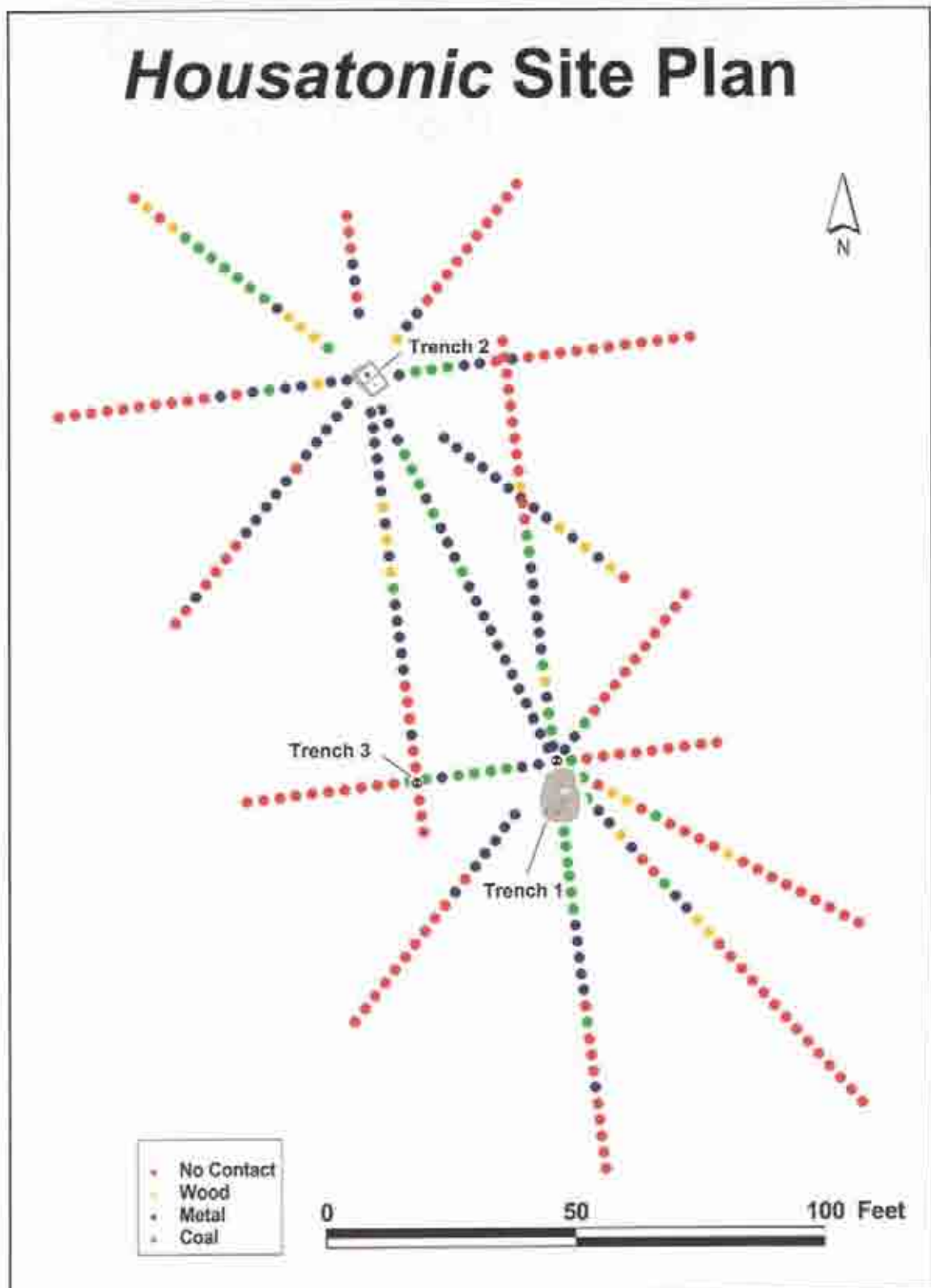


Figure 5.3. Housatonic site plan showing probe and test excavation locations.

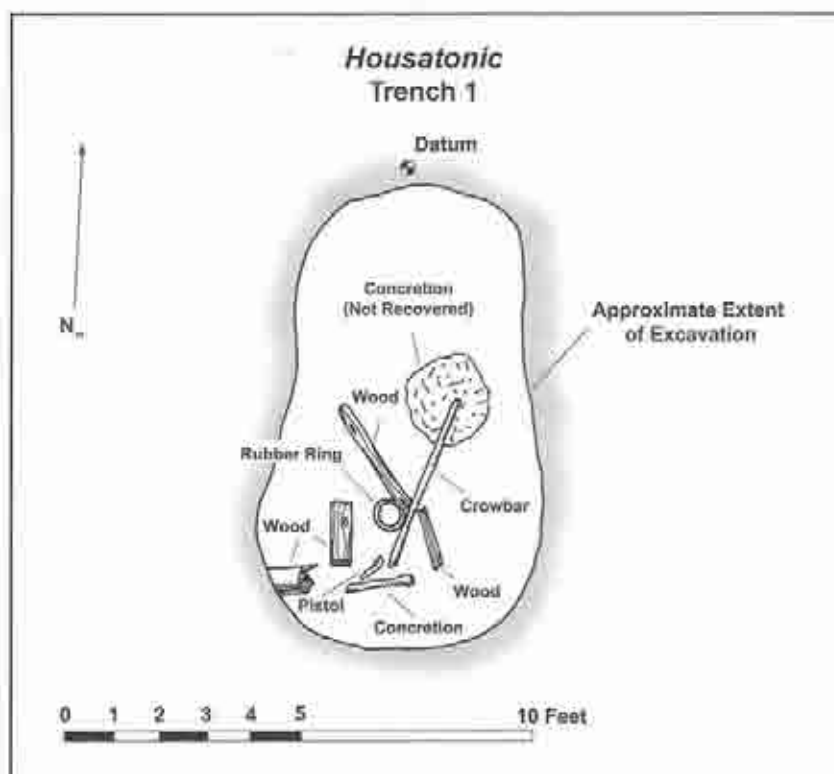


Figure 5.4. Trench 1.

003, 99-009, 99-011, 99-026 and 99-064) and a section of a sixth (Hunhou 99-028); a crowbar (Hunhou 99-038); two pieces of wood with dovetail joints (Hunhou 99-014 and 99-021) and a large rubber gasket (Hunhou 99-018) (Appendix A). A scarfed, slightly curved timber 2–3 in. (5.1–7.6 cm) thick and 7 in. (17.8 cm) wide was found protruding from the packed coal floor and could not be fully uncovered; sample (Hunhou 99-045) was taken from this timber. Another timber of undetermined length and 9 in. (22.8 cm) diameter was embedded in the southwest corner of the trench 2–3 ft. (.6–.9 m) above the packed coal surface; sample (Hunhou 99-024) was taken from this feature. In the center of Trench 1, a large concretion, probably a coal and iron conglomerate, was observed but not recovered. No attempt was made to excavate through the coal layer in the trench bottom.

TRENCH 2

The Trench 2 excavation was a roughly rectangular area 12 ft. (3.7 m) long, 8 ft. (2.4 m) wide and 4–7 ft. (1.2–2.1 m) deep. Principal features uncovered consisted of two iron tank-like objects 4 ft. 4 in. (1.3 m) long by 5 ft. 3 in. (1.6 m) wide buried 4 ft. (1.3 m) below the seafloor (Figure 5.5). The height of the tanks was not determined since they were not excavated to their bottom, but a probe sunk through the opening of the southernmost tank reached a depth of 4 ft. 7 in. (1.4 m). Each tank has an oval hole 1 ft. 4 in. (.4 m) long and 10½ in. (26.6 cm) wide in the top at its geometric center. The metal on the top of the tanks surrounding the open oval hole is ¾ in. (1.9 cm) thick. The two tanks are 1½ in. (3.8 cm) apart and oriented 62° magnetic on their adjacent sides. On the northwest corner of the

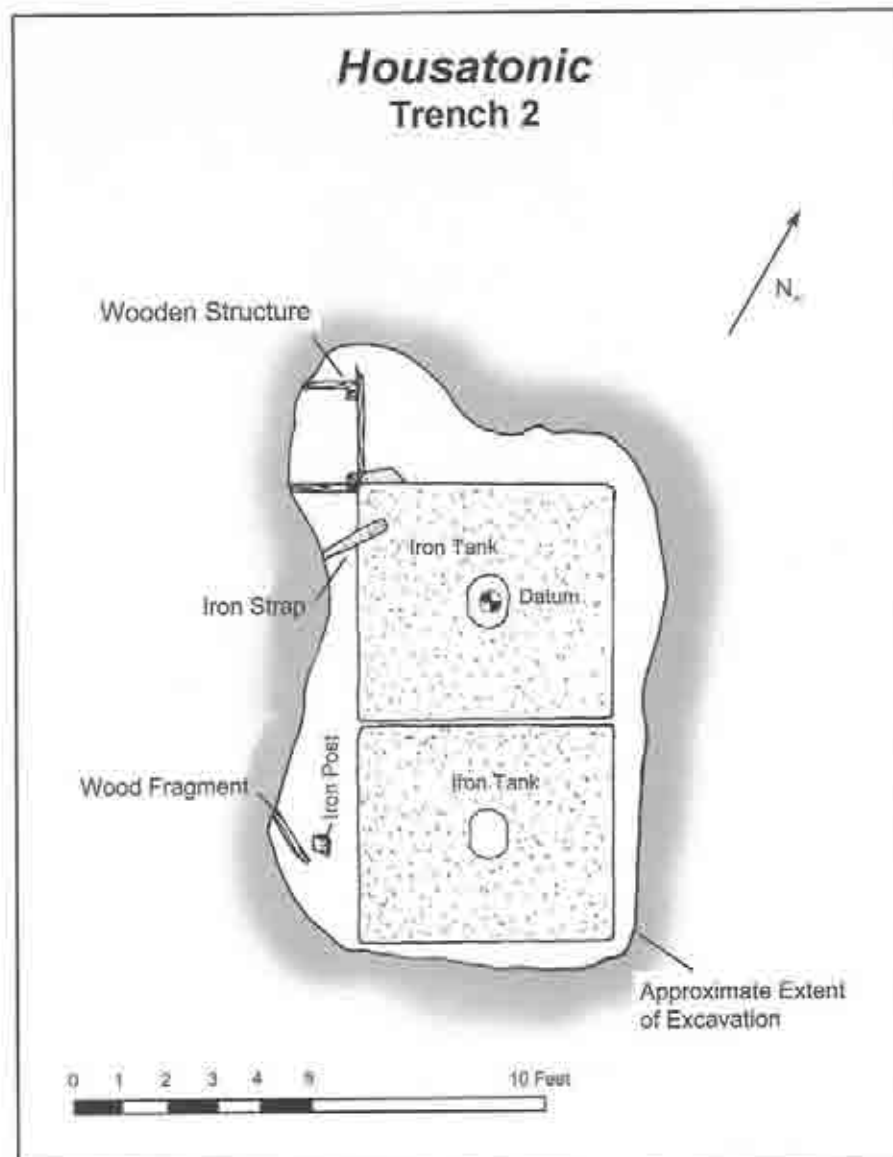


Figure 5.5. Trench 2.

northernmost tank, small sections of wooden structure were observed. The structure is comprised of horizontally laid planks approximately 16 in. (40.6 cm) wide and 3 in. (7.6 cm) thick, backed by upright square timbers 4 in. x 4 in. (10.1 cm x 10.1 cm). The preserved top of the wooden structure is 1 ft. 2 in. (.36 m) below the top of the adjacent tank. The wooden structure was not fully excavated, but it continues into unexcavated sediments in both

a vertical and horizontal direction. Directly west of the southernmost tank is a large, upright rectangular iron post or bar 6 in. (15.2 cm) wide and 4 in. (10.1 cm) thick of unknown length. This iron feature was not excavated to determine its length.

Thirty-two artifacts were recovered from Trench 2, almost all of which came from the northern side of the excavation below the level of the top of the northernmost tank. Artifacts

recovered include: several whole and fragmentary leather boots or shoes (Hunhou 99-053 through 99-059); a zinc fuse (Hunhou 99-064); a copper-alloy socket marked with the Roman numeral VIII (Hunhou 99-067); broken pieces of two different ceramic vessels (Hunhou 99-074, 99-075); part of a rifle (Hunhou 99-062); and a portion of a writing pencil (Hunhou 99-076) (Appendix A).

TRENCH 3

Trench 3 was the largest (approximately 15 ft. [4.6 m] long and 12 ft. [3.7 m] wide) and deepest (12 ft. below the seafloor) of the three test trenches excavated during the 1999 *Housatonic* assessment. As with the Third Anomaly, Trench 3 was documented in zero

visibility largely by feel, though occasional periods of relatively clear water produced visibility of up to a foot. Only a field sketch was made of this area (Figure 5.6), but several observations can be made.

Principal finds in Trench 3 were a large section of copper sheathing with a seam in it, some large timbers and a number of metal pipes. The copper sheathing lies beneath the other features and extends for at least 6 ft. (1.8 m) in length and an unknown extent into unexcavated sediment. Large pieces of coal and concretions were primary features in this trench.

Sixteen artifacts were recovered from Trench 3 including five copper-alloy drift pins (Hunhou 99-080, 99-083, 99-085, 99-087 and 99-091); samples of copper sheathing (Hunhou 99-094); several iron fastener

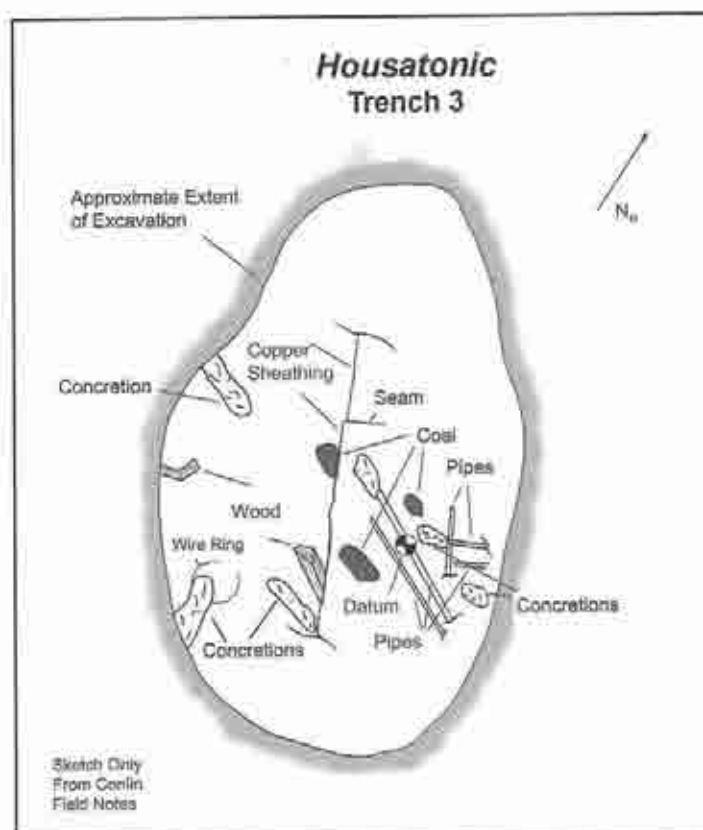


Figure 5.6. Trench 3.

concretions (Hunhou 99-081, 99-084, 99-088 and 99-089); an iron chain concretion (Hunhou 99-086); and a small brass chain and hook that was probably used as a sword carrier (Hunhou 99-090).

THIRD ANOMALY

The Third Anomaly sits approximately 430 ft. (131 m) east of the *Housatonic* wreck. The object producing the magnetic anomaly was documented in a preliminary manner largely by feel in almost zero visibility conditions. Because only a portion of the object was excavated, only a few descriptions can be made. The object producing the 160-gamma magnetic anomaly is large, roughly bullet-shaped, hollow and made of ferrous metal. It is

flat at one end and tapering to a blunt point at the other. Diameter is 8 ft. 7 in. (2.61 m) at its largest end and an unknown diameter at the smaller end, which was not excavated. It is approximately 7 ft. (213 m) long and lying on its side, largely buried in sediment. The object was found with a section of the round side and part of the large diameter flat end protruding approximately 9 in. (22.8 cm) above the seabed. The flat end of the object has a large oval hole in the area that protrudes above the seabed. This hole follows the curve of the exposed upper side of the object. Where the flat end joins the curving side is a rolled lip approximately $\frac{1}{2}$ in. (1.27 cm) high and 1 in. (2.5 cm) wide (Figure 5.7).

Attached to the side of the object is an approximately 8 in. (20.3 cm), semicircular piece

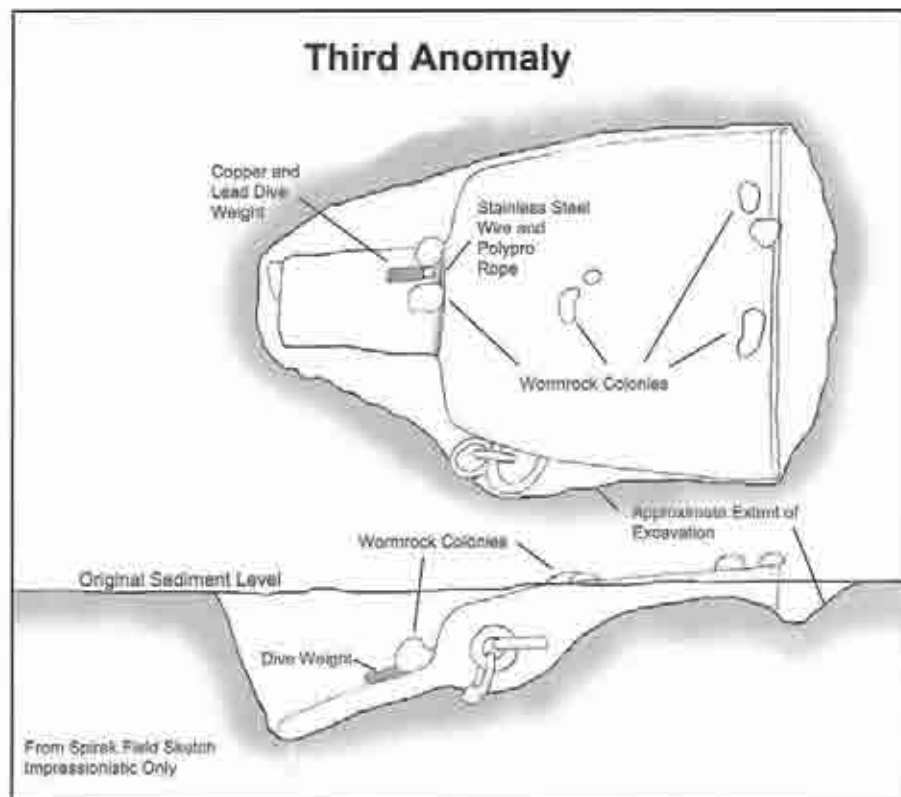


Figure 5.7. Diver's sketch of the Third Anomaly.

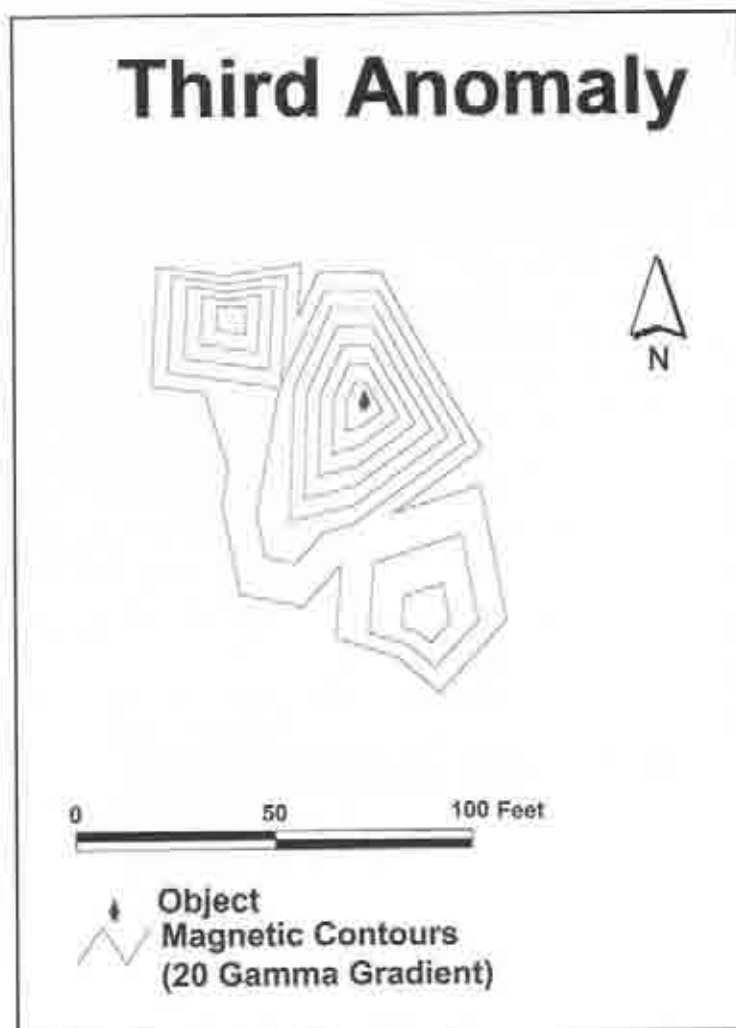


Figure 5.8. Third Anomaly magnetic data.

of round iron barstock $1\frac{1}{2}$ in. (3.81 cm) in diameter. Attached to this are at least two links of open-link chain 9 in. (22.9 cm) long. The chain disappears into the sediment and was not excavated to its full extent, though an examination of the magnetic contours derived from the 1996 *Hunley* survey indicate additional ferrous materials likely in proximity to the object in an unexcavated area (Figure 5.8). Next to the object, but not attached to it, is a piece of worked, round timber lodged in the sediment approximately 6 in. (15.2 cm) in diameter and of undetermined length.

Adhering to the object were three large colonies of wormrock. In addition to the wormrock, a length of $3/8$ -in. (.96 cm) diameter polypropylene rope and three strands of 4-mm (.16 in.) braided stainless steel wire were found attached to the object. The wire and rope ran through the brass handle of a homemade dive weight of copper pipe filled with lead. The wormrock had grown over and around the wire and rope. Additional wormrock colonies were attached to the object, but these had not grown around the wire. Both the wire and the dive weight, as well as a colony of wormrock were

recovered (Appendix A and Appendix B). The line and wire were designated Hunhou 99-001, the weight Hunhou 99-002 and the wormrock Hunhou 99-095.

FOURTH ANOMALY

The Fourth Anomaly is located approximately 450 ft. (137.1 m) northeast of the *Housatonic* wreck. It is a 6-gamma anomaly produced by a small Admiralty-type anchor connected to a length of open-link chain buried 5 ft. (1.5 m) under the seafloor (Figure 5.9). The links on the chain are 9 in. long and 5½ in. (13.9 cm) wide and made of 1½ in. (3.8 cm)

diameter barstock. Approximately 8 ft. (2.4 m) of chain were documented attached to the anchor. The anchor lies palm up with the shank horizontal. The shank length is approximately 5 ft. (1.5 m), mid-shank diameter is 4 in. (10.1 cm) and basal-shank diameter is 6 in. (15.2 cm) (Figure 5.10). The anchor palms are 7 in. (17.7 cm) wide, 1 ft. (.3 m) long and approximately 1 in. (.3 m) thick. The distance between palm tips is 3 ft. 6 in. (1.06 m). The top of the shank was not totally excavated; there was no indication of either a wooden or metal stock. The bearing of the shank is 195° magnetic. With 6° west magnetic variation as of 1994, and a 6-second annual increase, 195° magnetic measured in

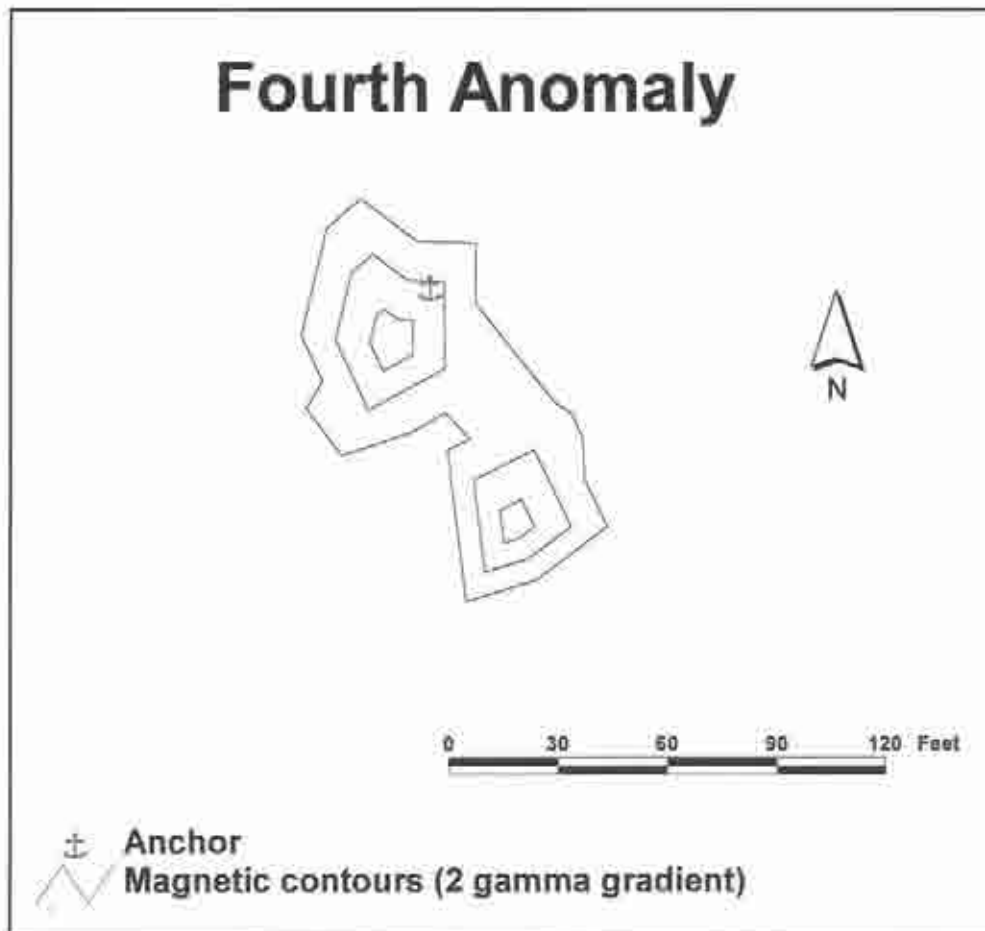


Figure 5.9. Fourth Anomaly magnetic data.

1999 translates into slightly more than $188\frac{1}{2}^\circ$ true.

ADDITIONAL OBSERVATIONS

Excavation and probing of the historically identified *Housatonic* wreck indicates superior preservation of even relatively small organic artifacts and intact structural elements in some areas. The features of the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site are contained within an area 1,640 ft. (499.8 m) long and 950 ft. (289.5) wide or approximately 1.5 million sq. ft. Archeological materials within this area are indicated by magnetic data contoured at a 2-gamma gradient. Assuming site extent is reflected by the magnetic contours, the area of the *Housatonic* wreck encompasses more than 128,000 sq. ft. (11,891.6 sq m) based upon the 2-gamma isoline. The area of contiguous probe contacts on the wreck is

approximately 7,300 sq. ft. (678.1 sq m) or 5.7% of the total area of the magnetic anomaly caused by *Housatonic*. The hull plans for an *Ossipee*-class sloop-of-war show the original area of the hull, prior to the attack and postdepositional scattering, as approximately 6,000 sq. ft. (447.4 sq m) or about 4.6% of the area of the 2-gamma anomaly contour. Total excavation area for the *Housatonic* assessment was approximately 336 sq. ft. 31.2 sq m), which amounts to 0.02% of the total area surveyed during 1996, 0.26% of the area of *Housatonic*'s 2-gamma magnetic anomaly; 4.6% of the total area of contiguous probe contacts; or 5.6% of the original hull area prior to the attack and postdepositional scattering. In summary, a systematic, but extremely minimal impact examination of a large and difficult site produced artifacts in a superior state of preservation, concrete data pertaining to wreck orientation and degree of preservation, and information directly pertinent to an understanding of the *Hunley* attack.

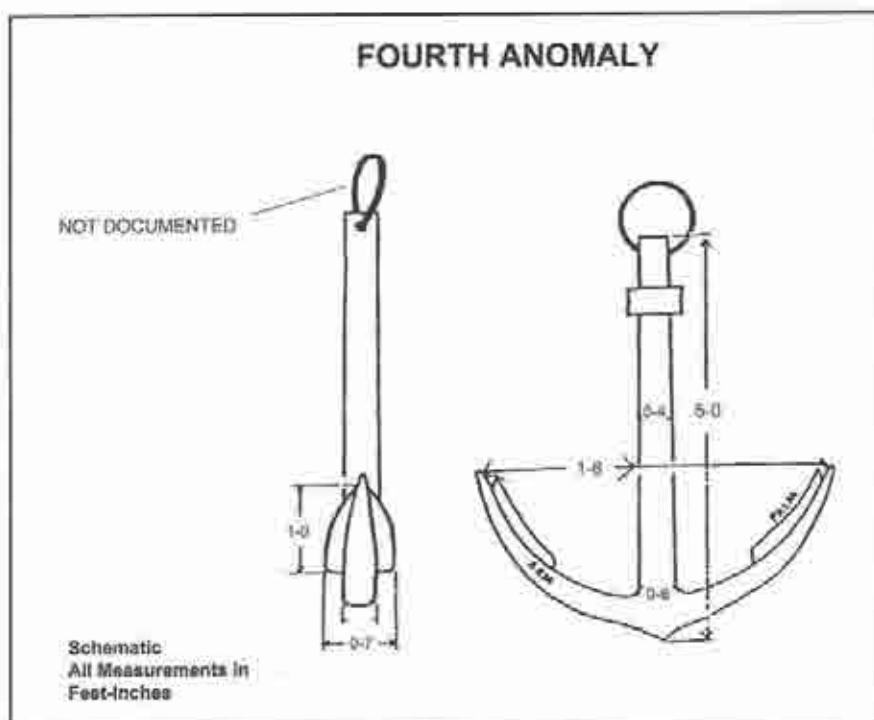


Figure 5.10. Fourth Anomaly measurements (not to scale).



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CHAPTER 6

Artifact Assemblage

Shea W. McLean and Claire P. Peachey

Wooden-hulled US Civil War naval vessels like USS *Housatonic* were constructed from a variety of materials including wood, textiles, leather, hemp, glass, rubber and several different metals. In addition, these complex ships contained a myriad of equipment, machinery, personal items, chemicals, supplies and weaponry. When recovered during archeological investigations as artifacts, these materials are often fragmentary, deteriorated and difficult to identify. Before interpreting individual artifacts, it is best to understand the diversity of objects that might be found on this kind of shipwreck and the different materials of which they are made. The following inventory quoted from the ledger of Gideon Welles, US Secretary of the Navy 1861–1869, provides a hint of the volume and variety of items utilized onboard blockading federal vessels (Welles 1863:434, 435):

Statements

Showing the amount of money expended by the Bureau of Construction, &c. of the Navy

Department from July 1, 1862 to June 30, 1863, for Timber and materials for the navy.

By Contract \$1,964,346.36

BY OPEN PURCHASE

| | |
|----------------------|-----------------------|
| <i>Timber</i> | \$834,253.10 |
| <i>Hemp</i> | 103,077.89 |
| <i>Copper</i> | 139,143.57 |
| <i>Miscellaneous</i> | 905,707.15 |
| | <u>\$1,982,181.71</u> |

Articles consisting of:

Iron, Iron Castings, Steel, nails, Rivets, Anvils, Chains, Iron wire, Cling rings, Spikes, Sheet brass, Copper wire, Copper nails, Stores, Chains, Carpets, Shades, Table [covers], Looking Glasses, mops, Dishcovers, Wicking, Chimneys, Lamp Reflectors, Furniture, Boat Apparatus, Hardware, Mast hoops, Brooms, Butts, Copper rivets, [-], Tacks, Curled hair, Twine, Log lines, Bunting, Dry Goods, Hair cloth, wool, Brass

cornice, Baize, Satinet, Velvet, Port lights, Glass, Silver glass, Reflectors, Binnacle lenses, Pitch, Tar, Rosin, Mathematical instruments, Stationery, Books, Pencils, Paint, Whiting, Water colors, Oars, Leather, Brushes, Bricks, Buff shine, Lead, Sheet Lead, Lead pipe, Pulverized black lead, White Lead in oil, White Lead dry, Dioptric lens, Rubber packing, Rubber valves, Hose, Rubber Hose, Sperm oil, Fish oil, Lard oil, Sweet oil, Tallow, Soap, Brown soap, Soft Soap, Canvass, Ravens duck, Burlaps, Mercury, Candles, Tools of iron, [Scrapers,] Rings, [German] lace cloth, Brass tubing, Thimbles, Steam pipe, Gaskets, Gunney bags, Cotton wash, Ship chandlery, composition fixtures, Sail Knives, Junk Knives, axes, Glue kettles, Pans, Pots, Stew pans, Chloride of Lime, Catgut, Cornmeal, Gum packing, Salt, Tin, Zinc, Spatter, Solder, Emery cloth, Webbing, Quartz, Scuttle Butts, Cat stoppers, mouth pieces, Blocks, Pulleys, Signals, Ensigns, Flags, Wood [screws], Shafting, Ratchet Wheels, Wheel [bearings], Articles of machinery, Wood, Coal, [Parcelling], Felting, Oil cloth, Tracing cloth, Gimps, Plush [frocks], Tufts, [Brussels] carpets, Boats, Fire bricks, Cement, Sand, Fire clay, Oatmeal, Sour flour, Brand, Hand & Leg irons, Sheathing paper, Sand paper, Emery paper, Fire plates, Grates, Grate bars, Oven doors, Caboose & fixtures, Sheathing metals, Sheathing nails, Shingles, Pumps, Steam pumps, Pump valves, Beeswax, Belting, Staves, Casks, Kegs, pipes, Unions, Elbows, Couplings, Cocks, Steam fixtures, Sheathing metals, Sheathing nails, Shingles, Shackles, Galleys, Thread, [Iron -], Hooks, Eyes, Sewing thimbles,

cleats, marline Spikes, Distillers, Lamps, anti-attrition metal, yellow metal, Brass Lights, [Hides], Chain Stoppers, Co[r]dage, Rigging, Lines, Washers, Raw Cotton, Worsted binding, Tape, Ticking, Damask table covers, Scales & weights, [Bushes], Holystones, Wood rasps, Saltwater soap, Potash, Grate linings, Gum shellac, Tube brushes, Fish hooks, Pipe racks, [Glacis] rings, [Sleeves] for Pilot Houses, Knives & forks, Tumblers, Sea kettles, Oil Cloth, Mirrors, Beeswax, Flues, Water closet basins, Clock springs, Chronometers, marine clocks, vacuum gauges, Salinometer, Salinometer glasses, Globe valves, Beam scale, Horn for Lanterns, Bellows, Green murveer, Bellows leather, Pump leather, Skins, Sand paper, Metallic tape lines, Gold leaf, Deck black, Green Glass, Pot glass, Turpentine, Dryers, Alcohol, Cans, Varnish, Photographs, Saisal and moulds, Boiler iron, [-] Stuff, Patent logs, Engine lathe, Danforth's blower, Sea kettles, Stakes, Mandrills, Oakum, [Trucks] packing, Sheet rubber, Packing Yarn, charcoal, Guano, Bag & Hammock Stuff, Flax, metal plating, Smith's [Dowl], Iron bolts, Deck and Hawser pipes, Anchors, windlass, mica, Gas pipes, Force pumps, Indicators and Steam fixtures, Chemicals, Patented articles &c. &c &c

Another document illustrating the wide range of material to be found on these vessels of war is the *Allowances Established for Vessels of the United States Navy 1864* issued by the Navy Department. Almost every artifact recovered from the *Housatonic* site can be found on these inventories.

During the 1999 fieldwork on the USS *Housatonic* wreck site, 94 artifacts and samples

were recovered from three small excavation areas. The artifacts recovered are only a small selection of what was present in the trenches and are not representative of the overall shipboard assemblage. However, they can illustrate many aspects of ship construction, shipboard activities, and material technology of the period, while their preservation and distribution can provide some clues to wreck formation processes (Chapter 9).

All artifacts were recorded in detail during the field season, then transported to the Naval Historical Center (NHC) conservation laboratory, Washington Navy Yard, Washington, DC for study and conservation. Eight concretion masses were sent to the Warren Lasch Conservation Center in North Charleston, SC (Chapter 7). Study and conservation of the artifacts is still in progress, so more will be learned as this work continues.

Significant artifacts are discussed below, grouped according to function or proposed function. All measurements were taken in centimeters and converted to inches. Scales used in line drawings throughout the chapter are in centimeters.

SHIP ARCHITECTURE

Archeological probe operations on the *Housatonic* wreck site indicate that a major portion of the ship lies buried deep beneath the seafloor mud (Chapter 5 and Appendix C). Very little of this structure was uncovered in the limited excavation carried out on the site. In the three small areas excavated, the only intact structural remains uncovered were the metal water tanks and adjacent interior wooden structure in Trench 2, and possibly some of the damaged outer hull structure, including copper sheathing, in Trench 3. However, many small, disarticulated objects related to the ship's structure were found and recovered; these were mainly fasteners, sheathing and fittings.

COPPER-ALLOY FASTENERS

Six long copper-alloy bolts (Hunhou 99-069, 99-080, 99-083, 99-085, 99-087, 99-091) and two copper-alloy tacks (Hunhou 99-081B, 99-093) were recovered from the site. With the exception of bolt Hunhou 99-069, all were found in Trench 3 scattered amongst iron fastener concretions, a large section of copper sheathing, possible wood hull remains and unidentified bar- or pipe-like features. Bolt Hunhou 99-069 was found in Trench 2 in the shelly matrix inside the oval opening of the southernmost water tank.

The six bolts are of a red-orange-colored copper alloy. All have splayed, peened heads and bulging or rounded-flat ends (Figure 6.1 and Figure 9.7). Bolt Hunhou 99-069 (Figure 6.2), 11.4 in. (29.0 cm) long, has a 1.9-in. (4.8 cm) diameter rove or washer preserved at the peened end, and its shaft is significantly thicker than the others, at 1 in. (2.6 cm). Bolts Hunhou 99-080 and 99-091 are straight, approximately 15.7 in. (40 cm) long, with a shaft diameter of 0.8 in. (2 cm). The other three bolts are bent, two in identical fashion, due to unknown causes. They are 9.8–10.6 in. (25–27 cm) long with a shaft diameter of 0.6–0.75 in. (1.4–1.9 cm). Bolt Hunhou 99-080 has two faint bands or grooves of what appears to be accelerated corrosion on the shaft, located 3.8 in. (9.7 cm) from the head and 3.0 in. (7.7 cm) from the end. These grooves may indicate where the bolt passed from one wood member to another.

These bolts are almost certainly more of the "copper bolts" recovered from the wreck by salvagers in 1874 (Chapter 2), used as hull fasteners below (and perhaps above) the waterline. As described in the *Boston Daily Advertiser* of November 21, 1861, the day after *Housatonic's* launch, *Housatonic's* hull was "copper-fastened below the load line." The disastrous effects of using iron fasteners below the waterline of copper-sheathed hulls had been known since 1782, when at least two British



Figure 6.1. Copper-alloy bolts. Naval Historical Center (NHC) drawing by James Hunter.



Figure 6.2. Hunhou 99-069 copper-alloy bolt with rove. NHC drawing by James Hunter.

naval vessels, HMS *Terrible* and HMS *Royal George*, sank due to galvanic corrosion destroying the iron hull fasteners. To prevent this galvanic corrosion, copper-alloy fasteners had been prescribed below the water line for Royal Navy vessels constructed after 1783 (Hay 1863:80; Bingeman et al. 2000:222; Chapelle 1967:207–208). After the patenting of Muntz metal, or “yellow metal,” by English metallurgist George F. Muntz in 1832, this 60–40 copper-zinc alloy, stronger and less expensive than pure copper, was widely used for fasteners, fittings and sheathing, but also was known to have problems with galvanic corrosion (Bingeman et al. 2000:224; Goodwin 1987:62). Future metallurgical analysis will determine the alloy used for *Housatonic*’s hull fasteners.

The two copper-alloy tacks from the wreck are most likely two of thousands of tacks used to fasten copper sheathing plates below *Housatonic*’s waterline. Tack Hunhou 99-093 (Figure 6.3) is short (1.3 in. [3.3 cm]) and slightly



Figure 6.3. Hunhou 99-093 copper-alloy tack. NHC drawing by James Hunter.



Figure 6.4. Hunhou 99-081B copper-alloy tack. Warren Lasch Conservation Center (WLCC) photo by Shea McLean.

bent, with a flat, circular head (diameter 0.4 in. [1.1 cm]) tapering on its underside to meet the shaft. The shaft has a nearly circular section at the head, gradually changing to a squared section (0.2 in. [0.4 cm]) and tapering to a point. Tack Hunhou 99-081B (Figure 6.4) was found within a concretion mass that included square iron fastener Hunhou 99-081A and coal bits. It is longer (2.4 in. [6.1 cm]) than tack Hunhou 99-093, with a flat, circular head (diameter 0.3 in. [0.8 cm]) and a round shaft (diameter 0.1 in. [0.3 cm]) tapering to a point. It is bent in several places.

IRON FASTENERS

Ten fragmentary wrought iron fasteners were recovered from the site, from all three excavation trenches. The most substantial remains came from Trench 3, where several copper-alloy fasteners were also found, along with copper sheathing and possible hull remains. All iron fasteners were encased within concretion masses and were identified first by x-radiography. If solid metal was visible, the

concretion accumulation was removed to reveal the fastener; if no metal remained, the corrosion void was cast with epoxy to create replicas of the original fasteners (Chapter 7).

The fragmentary fasteners have round (Hunhou 99-013, 99-020, 99-066, 99-084, 99-088A, 99-089), square (Hunhou 99-070, 99-071, 99-081A), or rectangular (Hunhou 99-039) shafts with the diameter or thickness ranging from 0.2–1.0 in. (0.5–2.5 cm), and preserved length ranging from 1.9–23.6 in. (4.8–60 cm) (Table 6.1). Several have remnants of deteriorated wood attached. Most are too fragmentary to be categorized (McCarthy 1996) with certainty. Only square spike Hunhou 99-081A (Figure 6.5) is fully preserved from head to tip. Hunhou 99-084 has a peened head and appears to be a bolt.

One of the longest fasteners, bolt Hunhou 99-089 (20.6 in. [52.2 cm] long, shaft diameter 0.5 in. [1.2 cm]), was preserved with significant amounts of associated wood and caulking inside the concretion mass (Figure 6.6). The head is capped by a countersunk wooden peg and sealed with what may be lead-based caulking. The bolt fastens three distinct timber fragments. The timbers are separated from each other along the bolt by oakum. The metal bolt itself had completely corroded away and was cast with epoxy.

COPPER-ALLOY SHEATHING

A corner piece of thin copper-alloy sheet, 99-094, was excavated from Trench 3, where a large expanse of sheathing, including a seam, was partially uncovered. This fragment was pried from the seam area (Figure 5.6) while two smaller samples were cut with snips from the long edge of the exposed sheathing. The corner fragment (Figure 6.7) has seven holes spaced unevenly around the edge; they are 0.2–0.3 in. (0.6–0.8 cm) in diameter, with rough,

splayed edges. No identifying marks are visible on the sheet (Bingeman et al. 2000:224–228).

Shipwrights have employed a variety of materials to provide bottom protection from the problems of rot, fouling and shipworm infestation. Hulls were sheathed with closely spaced iron or copper nails, zinc and lead, as well as nonmetal materials such as wood and various forms of encaustics (Steffy 1994:175; Bingeman et al. 2000:218–219). The British Admiralty experimented with copper by fully sheathing the thirty-two-gun frigate *Alarm* in 1761 (Hay 1863:80). Despite the initial problem of galvanic corrosion of the iron fasteners, copper sheathing became standard, as it was durable and remained clean for long periods. Ships sheathed with copper could travel faster, remain longer at sea and required less time in dry-dock for repairs and cleaning. The technique's first use on an American vessel was in 1781 on the frigate *Alliance* (Steffy 1994:175). By 1863, there was still much discussion as to what composition and manufacturing conditions of the copper produced the highest-quality sheathing; Hay (1863:92) reported in 1863 that Muntz's yellow metal sheathing had been used on 18 British Navy vessels and "it has appeared to wear well." Muntz metal sheathing was already being used widely on British merchantmen by the early 1860s (Bingeman et al. 2000:224).

According to Hall in his 1884 discussion of shipbuilding in the United States, copper sheathing was applied:

...to protect the bottom of the ship from the attacks of the teredo (a worm which burrows through the wood and completely honeycombs it with cells), and also to prevent it from becoming incrustated with barnacles and shells, which would greatly retard its motion through the water. The gradual

Table 6.1. Copper-alloy fasteners and iron fastener fragments.

| Hunhou no. | Type | Length (cm) | Maximum diameter (cm) | Head | Provenience |
|---|-------------|-------------|-----------------------|------|-------------|
| 99-069 | round | 29.0 | 2.6 | 3.3 | Trench 2 |
| | | | rove 4.8 x 0.6 | | |
| 99-080 | round | 40.8 | 2.1 | 2.9 | Trench 3 |
| 99-083 | round | 27.4 | 1.9 | 2.8 | Trench 3 |
| 99-085 | round | 25.6 | 1.4 | 2.2 | Trench 3 |
| 99-087 | round | 27.0 | 1.9 | 2.7 | Trench 3 |
| 99-091 | round | 40.2 | 2.0 | 3.0 | Trench 3 |
| Iron fastener fragments (or their epoxy casts) | | | | | |
| 99-088 | round | 4.8 | 1.5 | n/a | Trench 3 |
| 99-089 | round | 52.2 | 1.2 | n/a | Trench 3 |
| 99-013 | round | 26.0 | 2.0 | n/a | Trench 1 |
| 99-020 | round | 20.5 | 2.0 | n/a | Trench 1 |
| 99-039 | rectangular | 8.0 | 0.5 | n/a | Trench 1 |
| 99-066, 072 | round | 60.0 | 2.5 | n/a | Trench 2 |
| 99-070 | square | 2.5 | 2.0 | n/a | Trench 2 |
| 99-071 | square | 10.4 | 1.0 | n/a | Trench 2 |
| 99-081 | square | 14.0 | 1.1 | 1.9 | Trench 3 |
| 99-084 | round | 17.1 | 2.4 | 2.7 | Trench 3 |

**Figure 6.5.** Hunhou 99-081A radiograph of concretion showing wrought iron spike and copper-alloy tack. WLCC photo.

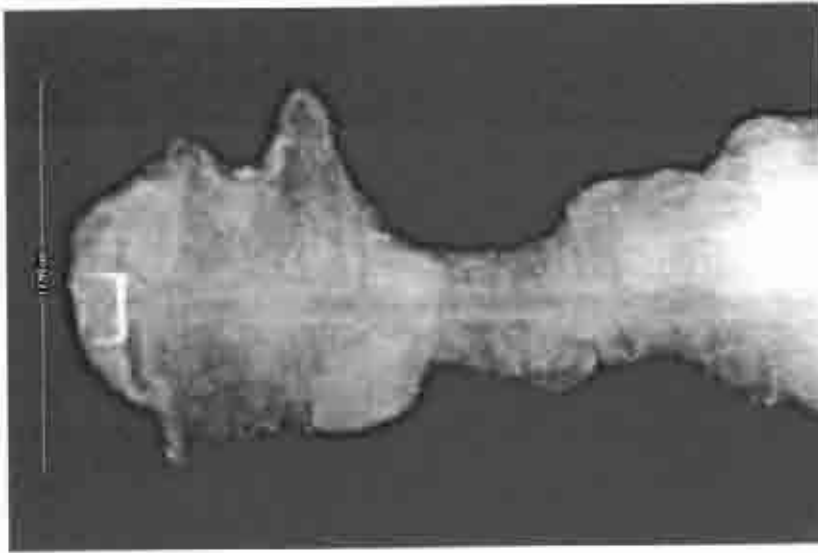


Figure 6.6. Hunhou 99-089 radiograph showing hollow mold of iron bolt with associated wood and caulking. WLCC photo.

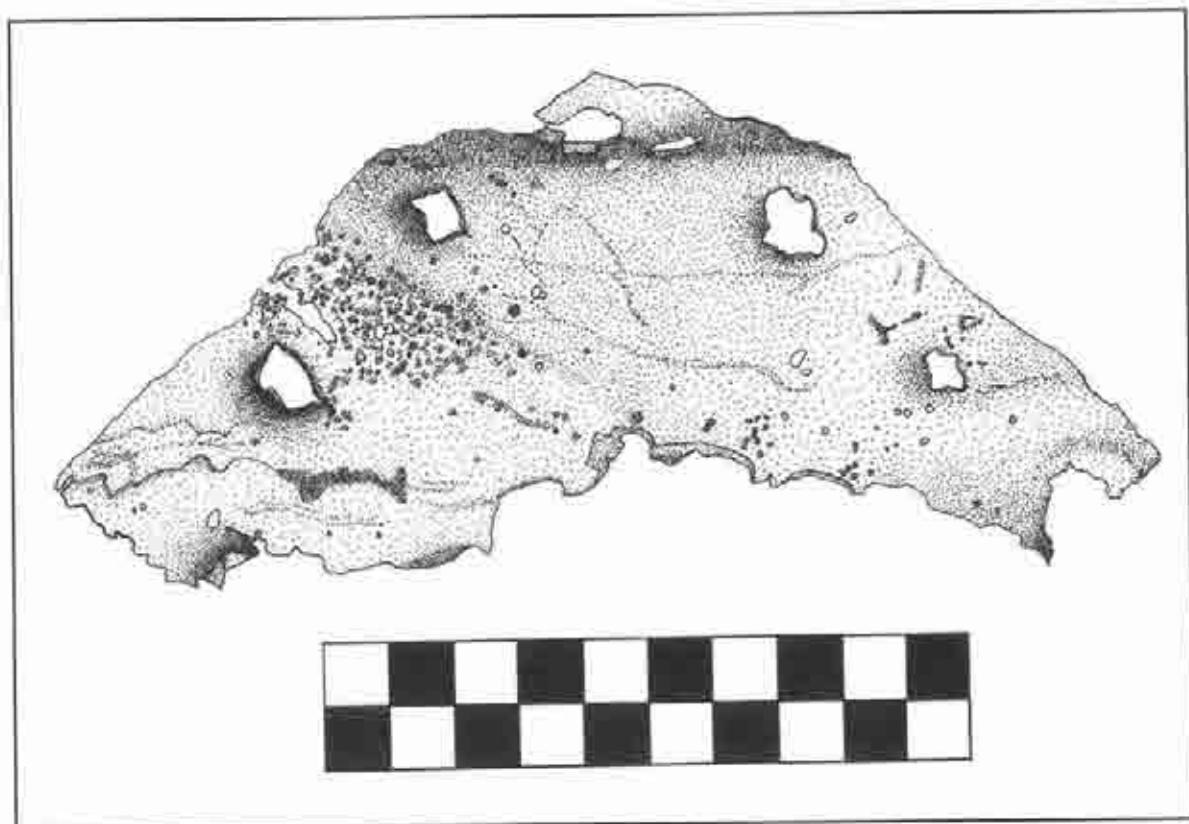


Figure 6.7. Hunhou 99-094 copper-alloy sheathing fragment. NHC drawing by James Hunter.

corrosion of the metal by salt water causes the barnacles to shell off as fast as they become attached and keeps the bottom of the ship smooth. It was not until the latter end of the last century that copper was introduced as a means of protecting the immersed part of the hulls of vessels, and the expense of pure copper soon led to substituting in its place an alloy called 'yellow metal', which was cheaper and answered the purpose well [Hall 1884:27].

Again, metallurgical analysis will determine if "yellow metal" or another copper alloy was used to sheath *Housatonic's* hull.

METAL FITTINGS

The term "fitting" refers to any fixed metal component (other than hull fasteners) associated with the operation of the ship. Load bearing fittings or fittings requiring strength are normally made of iron. Typical iron fittings include rigging components, chains, hoists, and windlasses. Fittings subjected to marine corrosion and not requiring an inordinate amount of strength are usually made of copper alloy.

Two copper-alloy fittings were found in the excavation of the wooden bulkhead area at the north end of the water tanks in Trench 2. They were part of a concentration of artifacts that included other items related to the ship's structure, such as iron fastener fragments and a pane of glass, and personal items, such as shoes and a pencil. This appears to be a mixture of items that fell from the decks above (Chapter 9).

A thin, narrow bar of copper alloy (Hunhou 99-061, 12.5 in. [31.8 cm] long, 1.5 in. [3.8 cm] wide, 0.4 in. [0.9 cm] thick) was found directly on top of, but not fastened to, the wooden bulkhead. It has a single, slightly angled fastener

hole for a countersunk screw (Figure 6.8). It appears to be a "bullnose" or fairing piece that would have been used to fair-in a slightly elevated tripping hazard or sharp edge of a metal plate. The hole is countersunk to accept a flat-head screw possibly indicating that it was attached to a wooden walking surface (Deans, personal communication 2002).

Also found in the same area of Trench 2 was a small copper-alloy socket (Hunhou 99-067). The socket is 4.0 in. (10.0 cm) high, with a shaft diameter of 1.7 in. (4.4 cm), and a 3.0 in. (7.7 cm) diameter flange at the top. The socket opening is 1.1 in. (2.8 cm) in diameter and 3.5 in. (9.0 cm) deep. The socket retains three of an original four countersunk slotted screws in the flange, and the Roman numeral VIII punched into the top of the flange (Figure 6.9). Fine parallel machining marks are preserved in the thin, black corrosion layer over the pitted brassy-yellow metal core. A prominent center-mark is preserved on the base, surrounded by fine concentric machining lines.

This fitting appears to be a flush-mounted deck socket, probably used for a $\frac{3}{4}$ -1-in. (1.9–2.5 cm) diameter removable handrail or canopy stanchion (Deans, personal communication 2002). The VIII stamped into it may indicate that it was part of a series of sockets arranged to accommodate correspondingly numbered rail or stanchion sections. Conlin (Chapter 9) interprets this to be a stop for one of the deck gun races.

A thin, wide, slightly curved strap of iron (Figure 6.10) was found immediately adjacent to and approximately 6 in. (15 cm) below the iron crowbar in Trench 1. It was completely covered in thick concretion but x-radiography shows it to be heavily corroded and to have two holes 1.1 in. (2.7 cm) in diameter along its center: an incomplete hole at one preserved end, and a second hole 15 in. (38 cm) away. This may be a fragment of the iron cross-strapping used in hull



Figure 6.8. Hunhou 99-061 copper-alloy bar. NHC drawing by James Hunter.

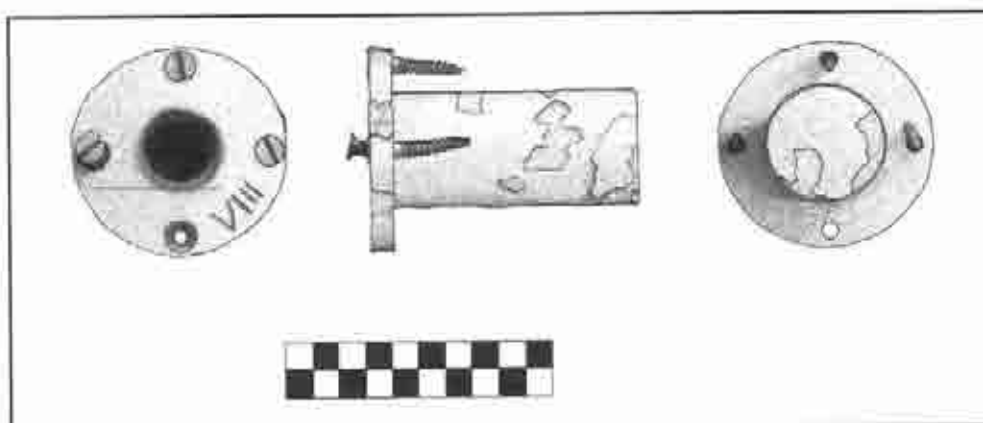


Figure 6.9. Hunhou 99-067 copper-alloy socket. NHC drawing by James Hunter.



Figure 6.10. Hunhou 99-017 iron strap. NPS photo by Brett Seymour.

construction, as described at *Housatonic's* launch: "The frame is of live oak... cross strapped with iron 4 ½ inches in width and five-eighths of an inch in thickness, placed about three feet apart. This bracing extends fore and aft the ship, and is bolted to each timber and crossing" (*Boston Daily Advertiser*, November 21, 1861). The strap is 36.2 in. (92.0 cm) long, 4.7 in. (12.0 cm) wide, and has a concreted thickness of 1.1 in. (2.8 cm). This form of construction strengthened and lightened large wooden ships and was probably in common use by the Civil War period (Goodwin 1987:104–105).

The iron strap (Hunhou 99-017) was provided to Krautkramer Branson Inc., a manufacturer of ultrasonic testing equipment, in order to test a probe to be used for ultrasonic hull thickness measurements on *H.L. Hunley*. The developers wanted to use a material that had the same date and similar technological and corrosion characteristics as *Hunley's* iron plates.

Another fitting was found inside one of the several concretion masses recovered from Trench 3. X-radiography revealed that most of these concretions are iron fasteners, but the x-radiograph of concretion Hunhou 99-086 clearly reveals a short, curved length of iron chain (Figure 6.11). No iron metal remains, and the concretion has not yet been broken open and cast with epoxy, but many details are visible from the x-radiograph. The chain is made up of ten links, each 1.2–1.4 in. (3.0–3.5 cm) long and 0.4–0.6 in. (1.0–1.5 cm) wide. Each link is made up of 0.2 in. (0.4 cm) diameter iron bent into a twisted figure-eight configuration; each loop of the "eight" is approximately 90 degrees to the other. The ends of each length of iron comprising a link appear flat. If the chain were straight, it would measure approximately 10 in. (25 cm) long.

A large, thick (0.1–0.5 in., 0.2–1.2 cm), roughly triangular sheet of lead, Hunhou 99-052, was one of few artifacts found in the sediment on the east side of the northernmost water tank

in Trench 2. It has irregular, torn, folded and curled edges with no fastener holes and is bent in several places. One surface has a 2.8 in. (7 cm) diameter, 0.6 in. (1.5 cm) high dome of lead on it. This object may have been lead scrap to be used as necessary for patches, repairs, weights, bullets, linings or other items. Hundreds of pounds of "lead, sheet" were carried on board navy vessels (Navy Department 1865:27, 82) for this purpose.

NONMETAL SHIP ARCHITECTURE

A small fragment of thin (0.2 in. [0.4 cm]), flat, clear glass, Hunhou 99-065, was found in the sediment on the NW side of the northernmost tank in Trench 2 near the bulkhead structure. It

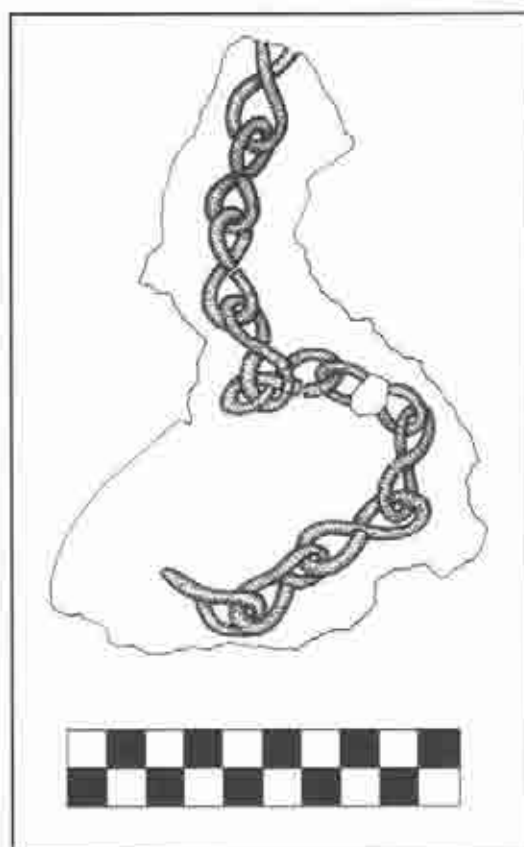


Figure 6.11. Hunhou 99-086 drawing of iron chain concretion from radiography. NHC drawing by James Hunter.

has only one preserved original straight edge, and no prominent manufacturing features such as surface texture or bubbles. It may have been part of a cabin window on the vessel, or perhaps part of a mirror whose metallic coating has deteriorated away.

ENGINE ROOM

USS *Housatonic* was a vessel powered by steam and sail. Nautically speaking, the age of steam arrived in 1807, when Robert Fulton's *Clermont* became the world's first commercially successful steam vessel. Although Fulton's paddle-wheel design revolutionized maritime propulsion, steam powered ships were somewhat handicapped during the first few decades of their implementation. Steam engines were often unreliable and in constant need of repair. In addition, the distance they could travel was limited according to the amount of coal they could carry. Consequently, most early steam vessels retained masts, rigging and sails. Sails could be depended upon to propel the ship when the engines were not working properly or the supply of coal had been exhausted. Equally important, sails could provide supplemental propulsion, thus reducing coal consumption over long voyages. By the late 1830s, paddle-wheel propulsion began to be replaced by screw propulsion for ocean-going naval vessels, primarily because of the excessive drag created by the paddle wheels when not in use. The huge side-wheel housings also created a windage problem and hampered a vessel's combat potential by reducing the number of batteries amidships (Canney 1990:17).

At the beginning of the Civil War, the federal fleet had only 24 steam-powered warships in active service (Canney 1990:91). A concerted effort was made to produce steam warships as efficiently as possible. The engines of *Housatonic* and its sister ships of the *Ossipee* class (*Ossipee*, *Juniata* and *Adirondack*) were

designed by Chief Naval Engineer Benjamin F. Isherwood. Isherwood's design incorporated the use of a two-cylinder back-acting engine with 42 x 30-in. cylinders with a 30-in. stroke (Chapter 2).

Housatonic's engines were made up of hundreds of independent parts. Each nut, bolt, screw, gauge, tube, gasket, pin, rod and spring undoubtedly required regular maintenance and periodic replacement. Trench 1 on the *Housatonic* site contained at least two artifacts that may have been part of the ship's engines. According to the reconstructed orientation of *Housatonic's* wrecked hull and the plans of *Housatonic's* sister ship USS *Ossipee*, Trench 1 is located in the area of the Engine Stores (Figure 9.10), where these parts may have been stowed.

A 10.4-in. (26.5 cm) diameter ring (Hunhou 99-018) composed of layers of textured rubber was found below the iron crowbar Hunhou 99-038, iron strap Hunhou 99-017 and wood board Hunhou 99-021 in Trench 1. The object has a circular cross section 0.9–1.3 in. (2.3–3.2 cm) in diameter and is composed of layers of natural rubber over what appears to be a core of solid or compacted rubber (Figures 6.12 and 6.13). Minor traces of what appear to be textile fibers remain. The object may be a gasket from the ship's engine (Deans, personal communication 2002). Gaskets (of a different type) are listed in the 1864 *Allowances* in the engineer's department: "Gaskets, 1/4" gum, spare sets.... For each man-hole, hand-hole, and mud-hole plate of boiler" and "Gaskets, 1/8" gum, spare sets.... For cylinder man-hole" (Navy Department 1865:25).

A hollow brass tube with a small piece of textured rubber attached (Figure 6.14) was also found in the same area of Trench 1, on the hard-packed coal floor, adjacent to pistol Hunhou 99-042 and a number of other small metal items. The 2.4-in. (6.2 cm) long, 0.6-in. (1.6 cm) diameter tube is crushed, and the ends are torn

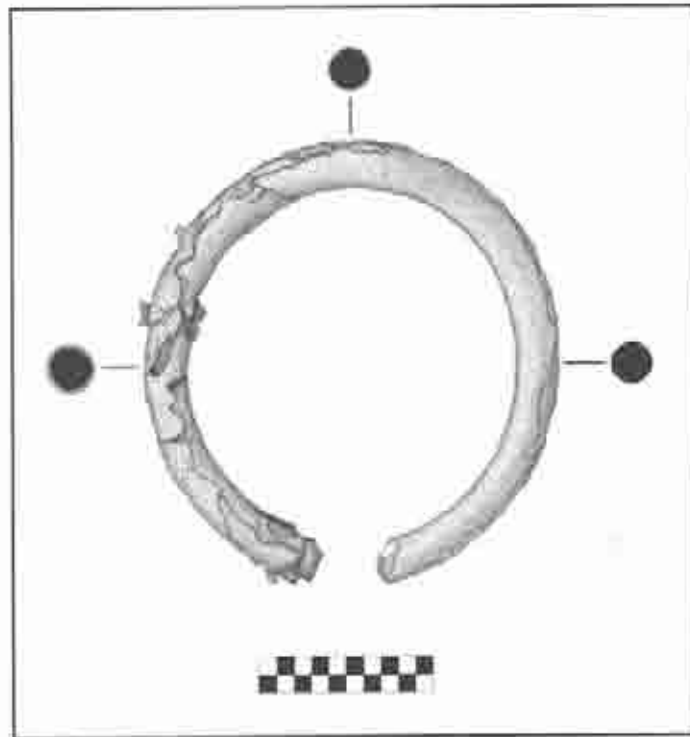


Figure 6.12. Hunhou 99-018 rubber gasket. NHC drawing by James Hunter.

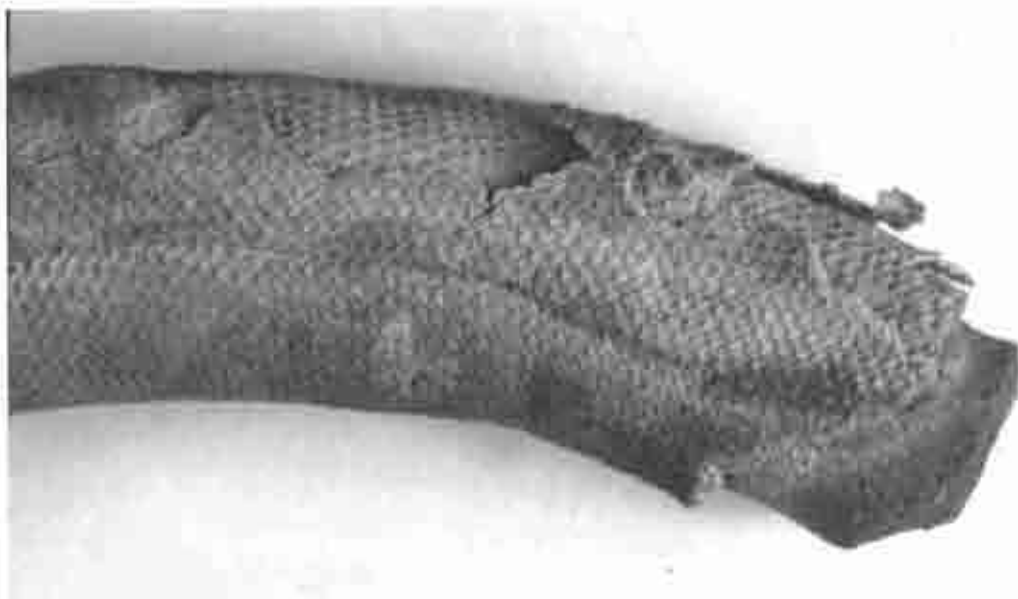


Figure 6.13. Hunhou 99-018 detail of rubber gasket. NHC photo by Claire Peachey.



Figure 6.14. Hunhou 99-034 brass tube with rubber fragment attached. NHC drawing by James Hunter.

and bent as if it were damaged forcefully. The object may be related to ordnance or is perhaps a fragment of the ship's machinery (the "brass tubing" of Welles' inventory).

COAL

Steam-powered blockading vessels consumed huge amounts of coal, as their boilers were kept lit at all times to allow them to intercept blockade runners or evade torpedo boats. *Housatonic* could accommodate 220 to 235 tons of coal in its bunkers (Canney 1990:95).

Large amounts of coal were found in all three excavation trenches on the site, as large chunks and fine dust. Several large pieces were raised as representative samples and may be analyzed in the future to determine provenience.

WEAPONS

As expected on the wreck of a military vessel, several items of weaponry were found on the *Housatonic* site, reflecting the different materiel used in waging war during this period. Warfare during the Civil War was an odd mixture of new technology and old tactics. Soldiers and sailors employed "Napoleonic" military tactics in an age of rapid weapons technology advances. The combination resulted in mass destruction and caused an incredible loss of life on both sides.

The two basic types of weapons used during the Civil War were edged weapons and projectile weapons. Edged weapons include swords, daggers, lances and bayonets. Projectile weapons, namely artillery and small arms, can be divided into two basic categories: smoothbore and rifled-bore weapons. Smoothbore weapons, as the name suggests, have a smooth surface on the inside of the barrel. Smoothbore weapons had a relatively short range and were not exceedingly accurate. Infantry units equipped with smoothbore rifles, for example, were rarely lethal at more than 100 yards. Consequently, infantry formations had to mass firepower in tight formations at close distances. The strategy was to overwhelm an enemy's position with masses of infantry. A typical battle was often decided at close quarters by bayonet.

Unlike a smoothbore musket, a rifled infantry musket could effectively engage and kill an enemy at nearly half a mile. Rifled weapons have spiraled grooves cut into the inner surface of the barrel giving them more accuracy at greater distance. Rifling was a relatively new innovation at the beginning of the Civil War. In fact, rifled ordnance was largely unheard of until

French army Colonel Treuil De Beaulieu introduced a six-grooved artillery prototype in 1842. Despite De Beaulieu's innovation and the limited use of rifled weapons in the Crimean War, the first successful application of rifled weaponry in warfare did not occur until the Italian campaign of Napoleon III in 1859 (Dickey and George 1993:14). The rifled barrel allowed projectiles to be fired further and with more accuracy than ever before. While smoothbore artillery was more effective against infantry in the field, walled fortifications and armor plating were especially vulnerable to rifled artillery. Prior to the Civil War, ships equipped with smoothbore guns were required to stack multiple decks with as many guns as possible to deliver a concentration of fire-power at close range. Rifled artillery enabled naval vessels to carry far fewer guns and effectively engage enemy vessels at longer ranges.

SMALL ARMS

Any projectile weapon that could be carried and operated by an individual soldier may be classified as a small arm. This includes shoulder arms and handguns such as pistols and revolvers. Shoulder arms are long-barreled firearms such as smoothbore muskets, rifled muskets, carbines and shotguns. The basic weapon of the Civil War soldier was the single shot, muzzle-loading, rifled percussion musket. The most widely used shoulder arm was the Springfield rifle manufactured by the Springfield Armory in Springfield, Massachusetts. The total production of this weapon approached 1.5 million by war's end. Confederate armories copied the Springfield design and produced an additional 64,000 rifles for use by Southern forces. Unable to produce enough muskets during wartime, both armies imported firearms from overseas manufacturers. The British-made Enfield rifle was similar in size and accuracy to the

Springfield and was used extensively by both armies (Woodhead 1991:22-27).

Four artifacts representing small arms were found on the *Housatonic* site. Most were found in Trench 1 on the hard-packed coal surface at the bottom of the trench. A stock cap (Hunhou 99-041) and a pistol (Hunhou 99-042) were found adjacent to each other along with a number of other small items, while a trigger guard (Hunhou 99-025) was a short distance away. Another trigger guard (Hunhou 99-062) was found with a concentration of personal items and ship fittings in the bulkhead area on the north side of the water tanks in Trench 2.

Enfield Rifles

A brass stock cap (Figure 6.15) and a two-part, brass trigger guard assembly (Figure 6.16) recovered from *Housatonic* are characteristic of British Enfield rifles (Figure 6.17). Similar fittings used on the US-manufactured Springfield rifles were made of ferrous metal. The brass surfaces of the excavated gun parts are deteriorated and scratched, but some manufacturing striations are preserved. Deteriorated wood is attached to the stock cap, and the trigger guard is bent out of shape.

With the exception of the US Model 1861 Springfield, the British Enfield was the most widely used small arm of the Civil War on both sides. The federal government purchased more than 500,000 Enfields over the course of the war and used them on land and at sea. The two-banded naval version (Figure 6.17) was fitted with a slightly heavier, shorter barrel and a side-mounted lug to accommodate a saber bayonet. The shorter version was preferred for shipboard use as it could be more easily wielded in close quarters, and the bayonet could double as a boarding cutlass when needed (Woodhead 1991:38).

The British Model 1853/58 Enfield rifle had the following specifications:



Figure 6.15. Hunhou 99-041 Enfield rifle brass stock cap with wood remnants. NHC drawing by James Hunter.



Figure 6.16. Hunhou 99-062 Enfield rifle brass trigger guard. NHC photo.

Caliber: .577

Weight: 8 pounds, 14.5 ounces

Weight of bullet: 530 grains

Maximum range: 1,100 yards

Model 1842 Aston Percussion Pistols

Fragments from two percussion pistols were excavated from Trench 1: a brass trigger guard assembly with iron remains (Figure 6.18), and a substantial portion of a pistol with wood, iron and copper alloy remains (Figure 6.19). Tenaciously embedded in the hard-packed coal at the bottom of Trench 1, the pistol was initially described by excavators as an unusual object that felt like “two strips of copper with a ball-like object.” This was the grip end of the pistol, with the “ball-like object” being the hemispherical brass grip cap.

Both Hunhou 99-025 and 99-042 appear to be from Model 1842 Aston pistols (Figure 6.20). Henry Aston’s Middleton, Connecticut factory produced more than 30,000 of these pistols for the Federal Ordnance Department between mid-1840 and mid-1850. Aston’s .54 caliber Model 1842 “horse pistol” was considered one of the best military single shot percussion pistols ever made. It had a barrel length of 8.5 in. (Woodhead 1991:38; McAulay 1992:124–126).

The nearly complete pistol (Hunhou 99-042) is preserved in two pieces from the brass grip cap to the brass barrel band, but with large areas missing. The hammer is missing, as are the end of the barrel and the wood of the grip. Exposed areas of wood in the lock plate and stock cap areas are in good condition. Most of the rest of the pistol is obscured by heavy concretion. A small area of the brass lock plate is exposed, but not the area that would carry the stamped factory marks to securely identify the manufacturer and date of the gun. Possibly these markings, usually located forward and to the rear of the hammer attachment site, are well preserved beneath the adhering concretion.

An x-radiograph of the pistol (Figure 6.21) shows clearly the springs and other components of the interior firing assembly, the cavity of the completely corroded trigger, a screw near the grip cap and preserved wood remains. The dimensions of trigger guard Hunhou 99-025 are virtually identical to those of the trigger guard on pistol Hunhou 99-042.

Two stamped marks are preserved in the deteriorated surface of trigger guard Hunhou 99-025. A tiny “W” is located on the upper, or inner, surface of the guard, and another “W” is on the forward tang (Figure 6.22). The letters “AA” are also inscribed on the lower, or outer, surface of the guard (Figure 6.23). All marks are faint, particularly the AA, which is in an area of heavy pitting and surface loss.

The stamped “W” is probably an inspector’s initial. Aston pistols were marked with the letter “W” by two inspectors: Lt. George Wells, USN, 1845–1862 and George Wright, 1850–1852 (Lanham, personal communication 2002). The more complete pistol may also be found to have inspector’s marks on it; if the date is preserved on its lock plate, it may be possible to identify which of the two inspectors marked it.

The letters AA on the bottom of guard Hunhou 99-025 appear to be hand inscribed, not stamped, so do not appear to be inspector or arsenal marks. It would not be implausible to surmise that the letters might be the initials of one of the members of *Housatonic*’s crew. Of the *Housatonic* crew members listed in USS *Canandaigua*’s logbook entry for February 17, 1864 (National Archives, Washington, DC), only one individual was found with the initials “AA”. Although Andrew Anderson is officially listed as the ship’s cook, there is evidence that he would have been issued a firearm at some point. Anderson is listed as one of the soldiers and sailors who took part in an assault on Fort Sumter on September 9, 1863. Anderson, unlike many of his comrades, survived the battle and made his way back to the blockading fleet (ORN



Figure 6.17. Replica of the British Model 1858 two-banded naval Enfield. NHC photo.



Figure 6.18. Hunhou 99-025 pistol brass trigger guard. NHC photo.



Figure 6.19. Hunhou 99-042 Model 1842 Aston pistol excavated from *Housatonic*. NPS photo by Brett Seymour.

Figure 6.20. An example of the Model 1842 Aston pistol similar to the one found on *Housatonic* (courtesy NHC).

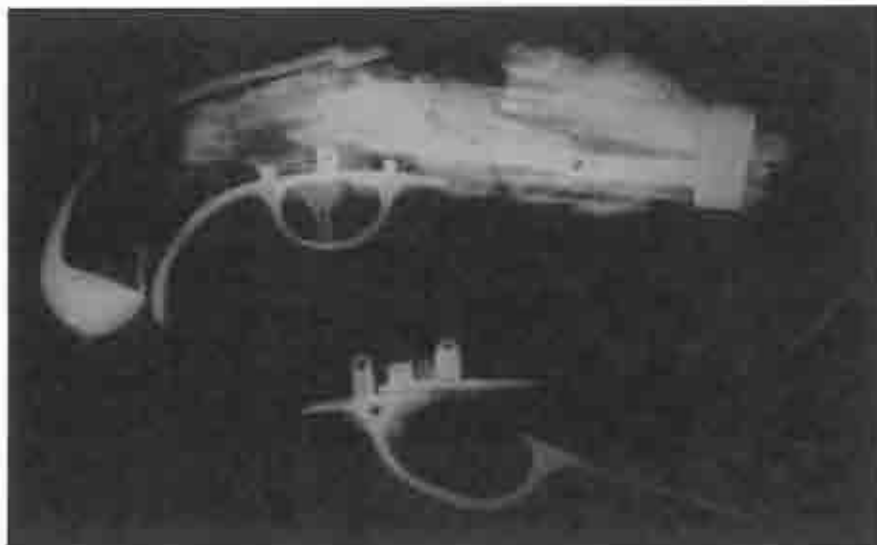


Figure 6.21. Radiograph of Hunhou 99-042 pistol (top) and 99-062 Enfield trigger assembly (bottom) (courtesy of Medical University of South Carolina).



Figure 6.22. Hunhou 99-025 stamped W on trigger guard tang. NHC photo by Claire Peachey.

ser. 1:14:617). He remained aboard *Housatonic* until its sinking and is listed in USS *Canandaigua*'s logbook as one of the men rescued.

ORDNANCE AMMUNITION

Artillery projectiles used during the Civil War came in a variety of shapes, calibers and sizes. One reason for such variety was due to the large number of gun manufacturers. Many gun types were named after their inventor or manufacturer: Dahlgren, Parrott, Whitworth, Rodman, Blakely. In addition, most inventors and manufacturers had differing opinions as to which projectile was best suited to the relatively new rifled guns. As a consequence, munitions manufacturers experimented with many different types of projectiles, designed to perform different functions. Civil War projectiles can be broadly categorized into five basic types: solid

shot, shell, case shot, canister and grapeshot (Dickey and George 1993:16–17). Ammunition in the form of grapeshot and artillery fuses was found on the *Housatonic* wreck site.

GRAPESHOT

A large, heavy, amorphous concretion (Hunhou 99-078) found in the bulkhead area of Trench 2 turned out to be a solid cast iron ball in excellent condition. It is 2 in. (5.0 cm) in diameter and weighs 12.6 oz (356 g). A clear casting line and sprue are preserved. Its size indicates that it is grapeshot (Figure 6.24).

Originally, grapeshot was simply a group of iron balls mounted on a wooden sabot, wrapped in cloth and twine. The twine wrapping was stitched between and around the iron balls, giving the projectile the appearance of a cluster of grapes. When fired, the cluster would disintegrate on impact, discharging the iron balls. By the time the Civil War began, grapeshot had been abandoned by most land artillery units in favor of the more effective canister shot. However, grapeshot continued to be an effective projectile when employed against naval vessels. Consequently, a modified grapeshot was utilized by naval forces until the end of the war (Dickey and George 1993:26). The “stand of grape” consisted of three layers of three solid cast iron balls held together by an iron disc bolted at each end. The balls were held in place between the discs by two iron rings (Figure 6.25).

ARTILLERY FUSES

Solid shot, canister shot and grapeshot required nothing more than the force of their propellant charge to inflict maximum damage. However, case shot and shell required detonation with fuses.

Like the various projectiles they were designed for, Civil War artillery fuses came in many different shapes and sizes and could be



Figure 6.23A. Hunhou 99-025 incised AA on bottom surface of trigger guard. NIIC photo by Claire Peachey.



Figure 6.23B. Markings traced for clarity.

used in a variety of different ways. They were made from different metals and fit a large number of projectiles of various calibers. The primary purpose of the fuse was to detonate a projectile above or amidst enemy forces. Fuses can be categorized into four types: time, percussion, concussion and combination (Melton and Pawl 1996:20). Fuses of the time and percussion types were found on the *Housatonic* site.

Time fuses were the most commonly employed during the war. They consisted of a metal or wooden plug with a premeasured paper or soft metal cartridge inserted into the center of the plug. As the projectile was fired, the hot gases produced during the combustion process ignited the cartridge. The artilleryist simply cut the paper or pierced the soft metal at the numbered interval on the cartridge in which he wished the projectile to explode (Peterson 1969:107–110). If he estimated that a projectile would take four seconds to reach the enemy's position after leaving the muzzle, for example, he would cut the cartridge at (along) the number "4" on the insert. Time fuses were usually employed to explode over enemy positions to inflict maximum damage on enemy personnel underneath.

Percussion fuses were designed to explode when a projectile made physical contact with a solid object. Most fuses of this sort employed a hammer-and-anvil approach to detonation. When the fuse struck a solid object, the impact would push a pin into a percussion cap seated on a nipple above the powder chamber within the projectile. However, if the projectile turned in flight and the fuse did not make direct contact upon impact, the projectile might not detonate.

Six zinc artillery fuses were excavated from the *Housatonic* wreck site: Hunhou 99-003, 99-009, 99-011, 99-026, 99-028 and 99-064 (Figure 6.26 and Table 6.2). Five of the six fuses were found scattered on the hard-packed coal floor of Trench 1, along with rifle and pistol parts, other small metal items, and wood box

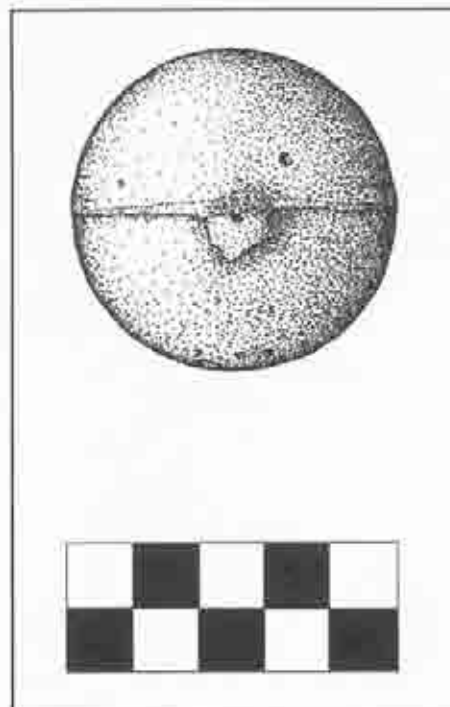


Figure 6.24. Hunhou 99-078 iron grapeshot. NHC drawing by James Hunter.

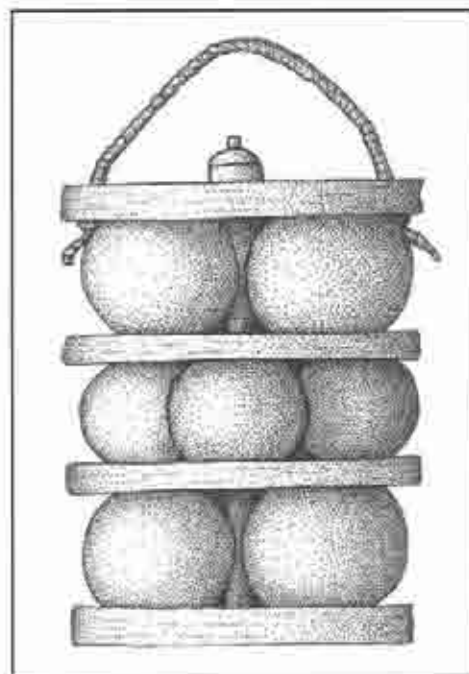


Figure 6.25. Typical grapeshot assembly. NHC drawing by James Hunter.

fragments. One fuse was found in Trench 2 amongst the concentration of artifacts at the northwest corner of the water tanks.

Five of the fuses are nearly identical time fuses. Each is somewhat cylindrical in shape, approximately 3.5 in. (8.8 cm) long, with its lower half smooth and its upper half threaded, and topped by a thick, wider flange. Fuse Hunhou 99-026 (Figure 9.13) has what appears to be a thin rubber gasket preserved immediately under the head or flange. X-radiographs reveal that each has a screw insert of dense metal, probably brass, over which is a lead patch with the appearance of a pull-tab (Figure 6.26). All are corroded and coated in heavy concretion, obscuring most details, including any keyholes and markings that may be preserved on the head.

The size, shape and composition of the five time fuses indicate they are Parrott fuses, which, unlike most fuses, were often made of zinc. The length of threads, width of head, and length of taper are consistent with 30-pounder Parrott fuses (Melton and Pawl 1996:24–26). There were at least four Parrott rifles aboard *Housatonic* at the time of sinking: three 30-pounders and one 100-pounder (Silverstone 1989:42; ORN ser 2:1:104). Named for their

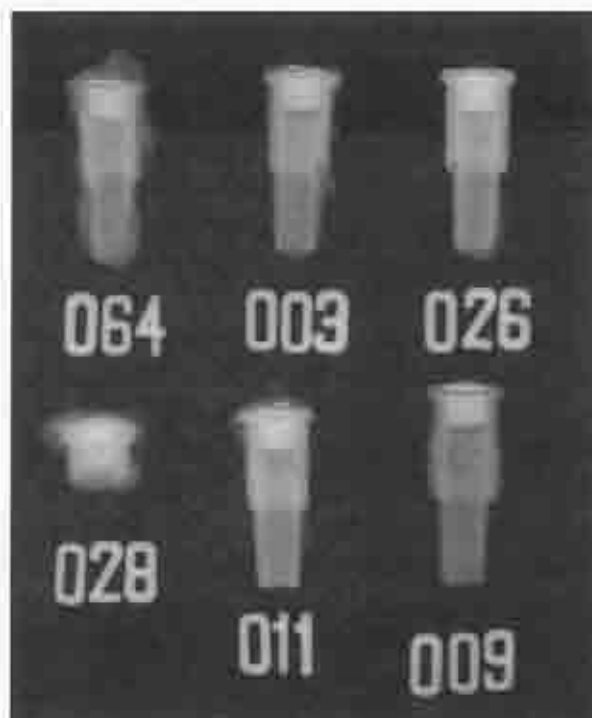


Figure 6.26. Radiograph of zinc artillery fuses from *Housatonic* (courtesy Navy Explosive Ordnance Disposal).

inventor, Robert Parker Parrott, these guns were distinguished by a single reinforcing band around the breech of the iron tube. A typical 30-pounder Parrott rifle had the following characteristics (Peterson 1969:106):

Table 6.2. Zinc Parrott fuse dimensions.

| Hunhou No. | Length (cm) | Maximum Diameter (cm) | Minimum Diameter (cm) | Provenience |
|------------|-------------|-----------------------|-----------------------|-------------|
| 99-003 | 8.7 | 4.0 | 1.8 | Trench 1 |
| 99-009 | 8.8 | 3.2 | 2.0 | Trench 1 |
| 99-011 | 8.5 | 3.5 | 1.7 | Trench 1 |
| 99-026 | 8.6 | 3.3 | 1.8 | Trench 1 |
| 99-028 | 3.6 | 3.5 est. | 2.8 est. | Trench 1 |
| 99-064 | 9.1 | 3.8 | 2.0 | Trench 2 |

| | |
|-------------------------------|-------|
| Bore diameter (inches) | 4.5 |
| Length of tube (inches) | 136 |
| Weight of tube (pounds) | 4,200 |
| Weight of projectile (pounds) | 29 |
| Weight of charge (pounds) | 3.75 |
| Range at 5d elevation (yards) | 2,200 |

According to the Ordnance Instructions for the United States Navy:

All spherical shells, except the 24 and 12 pdr. howitzer and all shrapnel, are fitted with the 'navy time fuze.' This fuze is composed of a composition driven in a paper case, and then inserted in a metal stock, which screws into a bouching fitted to the shell. The composition is covered with a 'safety cap,' which protects it from moisture and accidental ignition; also with a *water cap* of peculiar construction, intended to protect the flame from being extinguished on ricochet. A 'safety plug' at the lower extremity prevents the communication of fire to the powder in the shell in the event of the accidental ignition of the fuze after being uncapped [Navy Department 1864: Part II, 347].

Further details of the water cap and lead tab are described in Simpson's treatise on naval gunnery:

The paper case, after the composition is driven, is cut off to the required length and placed firmly in the metallic case. After the paper case is placed, a contrivance, called a *water cap*, is screwed in over the composition; this contrivance has for its object the preventing the entrance of any matter, such as sand or water, over which the shell may ricochet, and is primed on its outer

surface with a little powder and strands of quick-match. Over all is placed a leaden patch which securely guards the priming against moisture, and which must be removed at the time of entering the shell in the bore, or the shell will not explode [Simpson 1862:Art. 385].

Shorter fuse Hunhou 99-028 appears to be a zinc anvil cap for a Parrott percussion fuse. In this type of fuse, a sliding disc with a musket nipple and percussion cap was fitted into the hole of the cap and covered with a thin metal domed top. Upon impact, the dome would be crushed, allowing the anvil to strike the percussion cap (Melton and Pawl 1996:24-25; Dickey and George 1993:460; Kochan, personal communication 2002).

EDGED WEAPONS

The term "edged weapons" pertains to any sharp metal weapon intended to cut, slash or pierce. Edged weapons include items such as swords, daggers, lances, bayonets and their associated accoutrements. A single brass sword keeper (Hunhou 99-090) was found in Trench 3, one of the few items from that trench that is not related to the ship's architecture.

The sword keeper consists of two interlocked, thin, bright yellow brass chain portions (Figure 9.20). The oval link (1.2 in. [3.0 cm] long) has flat ends butted together to close the link. The hook link (1.4 in. [3.6 cm] long) is U-shaped, with one end bent fully around the oval link to attach it, and the hook end slightly flattened and flared outward to receive the sword assembly. The metal diameter is 0.1 in. (0.3 cm).

During the war, swords were worn by officers, noncommissioned officers (NCOs), and enlisted personnel. Naval enlisted ranks were issued cutlasses mounted in leather carriers or

“frogs” for purposes such as repelling boarders or cutting rigging during battle. Officers’ and NCOs’ swords, however, were usually more decorative than useful and served primarily as a symbol of rank. They were carried suspended from a plain, black, glazed leather belt “...not less than one inch and a half nor more than two inches wide, with slings of the same not more than three quarters of an inch wide, and hook in the forward ring to suspend the sword. Belt plate of yellow gilt in front, two inches in diameter, as per pattern. The belt to be worn over the coat” (US Naval Regulations 1864) (Figure 6.27).

CLOTHING

When *Housatonic* sank rapidly on February 17, there was no time for the crew to gather clothing or other possessions. Capt. John Keyes Crosby, watch officer on deck on the night of the sinking, wrote in a letter to his wife two days after the event, “I am in good health, but have no clothes. Being officer of the deck at the time of the disaster, however, I have the



Figure 6.27. Officer’s belt with brass sword hook (courtesy NHC).

clothes I wore then, but some of the officers have only their shirts.” (*Boston Traveler*, September 17, 1937). Another, quite colorful letter by Captain Joseph W. Congdon, sailing master of *Housatonic*, describes the plans the crew had made to save their possessions in the event of an attack:

So before turning in at night, each one of us officers would attach a line to our valuables and lead the line up through the hatch on deck, making it fast handy so that when the time did come for us to leave, we could clutch our lines, haul up our valuables and take them along with us just as easy as rolling off a log. I will state right here that when this anticipated event did come off, there was not a line picked up – so much for plans

. . . [my wife] anxiously awaited my return which duly came about, clothed in raiment made up of everybody’s odds and ends from other people’s wardrobes” [Nantucket Historical Association 1980].

It is not surprising, then, that personal items and remains of footwear were preserved on the wreck.

LEATHER BOOTS

Eleven leather footwear parts were excavated from the site, representing at least seven different boots: Hunhou 99-053A/B/C, 99-054, 99-055, 99-056A/B, 99-057, 99-058A/B and 99-059 (Figures 6.28, 6.29 and 9.15). All came from a small, deep excavation area in Trench 2, alongside the wooden bulkhead at the north end of the water tanks. They were buried with many other personal objects and small ship fittings that probably collapsed from the decks above (Chapter 9).



Figure 6.28. Hunhou 99-056B leather shoe as excavated. NHC photo by Claire Peachey.

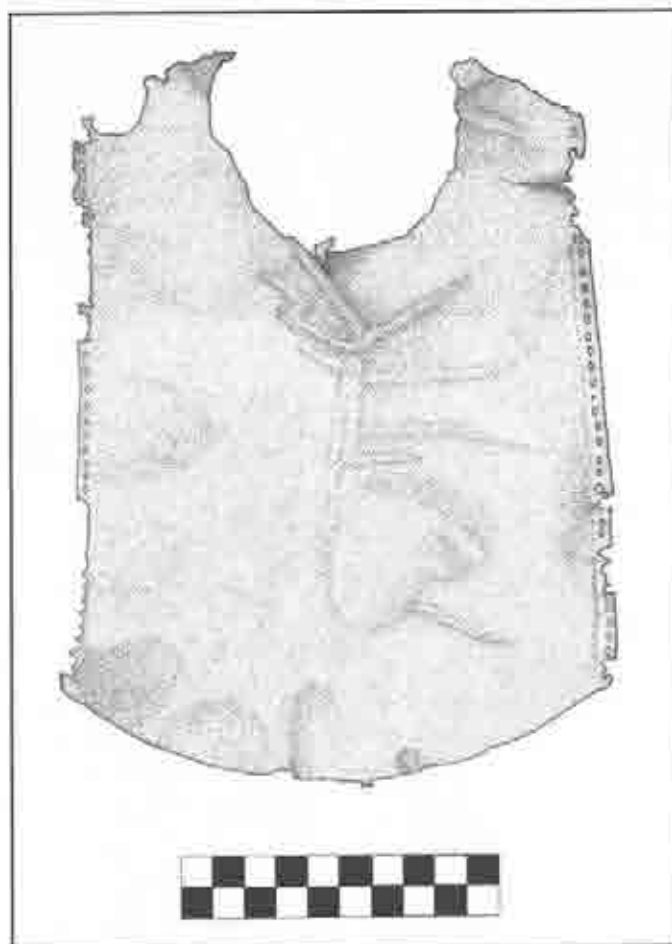


Figure 6.29. Hunhou 99-059 leather boot leg fragment. NHC drawing by James Hunter.

Three of the footwear parts have substantial sole and upper remains (Hunhou 99-054, 99-055, 99-056B), one is the front leg section only (Hunhou 99-058A), three others are soles only (Hunhou 99-053A with a heel, Hunhou 99-053B, 99-056A with some upper), two are upper fragments only (Hunhou 99-053C, 99-059), and one is a heel only (Hunhou 99-057). Most identifiable pieces appear to be from boots rather than shoes. Six of the boots are for a left foot, only one is for a right foot. None of the pieces with a sole is preserved above ankle height, but upper fragment Hunhou 99-059 appears to be the front leg portion of a mid-calf boot.

All soles are 11.0–11.8 in. (28–30 cm) long, with a ball width of 3.5–3.8 in. (8.8–9.7 cm). The instep width ranges from a very narrow 1.8 in. (4.5 cm) to 2.6 in. (6.7 cm). The preserved heels are built of three to five heel lifts (Table 6.3).

Soles and uppers were not sewn together, but were fastened by wood pegs and metal nails. Fasteners used in the soles are primarily single or double rows of diamond-shaped wooden pegs, each shoe showing slightly different spacing and size of pegs. Toe and heel areas have metal nails instead of, or in addition to, the wood. The most common arrangement is a single or double row of white metal (probably zinc) nails at the toe, and a row of square iron cut nails at the heel, though different combinations are seen within this small group. The presence of metal fasteners at the toe probably indicates that a shoe was machine-pegged on an early model machine that could not place pegs around the curved toe (Saguto, personal communication 2002). No indications of buckles or eyelets are preserved.

Although ankle-high, lace-up boots known as “brogans” or “bootees” are typical military footwear of the period (Zierden et al. 1995:n.p.; Lord 1963:310), none of the remains excavated from *Housatonic* appears to have this type of construction. Vertical seams at the ankles of

the *Housatonic* examples are indicative of a taller boot style, such as that found on the excavation of USS *Cairo* (NPS 1971:54; Lord 1975:31). Most appear to be “Wellington”-style boots (Saguto, personal communication 2002).

Naval uniform regulations of the 1850s and 1860s spell out the detailed requirements for uniform components such as hats, trousers, coats, buttons, shoulder straps and insignia, but specify little in the way of shoes. According to Todd (1978:536), for petty officers and seamen, “black shoes, of a low cut, were part of the regular clothing issue, but no information has been found on their pattern.” Photographs of crewmen aboard vessels during the Civil War show officers and sailors wearing a variety of shoe styles including lace-up, ankle-high shoes, lower-cut shoes with a buckle, and higher-cut boot styles, the full height of which are covered by the wearer’s pant legs (Figures 6.30 and 6.31). The 1864 *Allowances* specifies the footwear allowance on a Navy vessel for two years per 50 men as: boots 50 pairs, calf-skin shoes 100 pairs, kip-skin shoes 50 pairs and woolen socks 200 pairs (Navy Department 1865:140).

Another item possibly associated with clothing is a brass pin that appears to be part of a buckle (Hunhou 99-066B) found inside a concretion mass along with an iron fastener (Hunhou 99-066A). This mass was found in the concentration of artifacts at the north end of Trench 2 that included several leather shoe parts, but the buckle is too large to be part of a shoe. The 2 in. (5.0 cm) long pin has a sheath of thinner metal (probably also brass) around it, making the full diameter 0.2 in. (0.5 cm). The sheath appears to be the buckle roller. The item is too fragmentary to be sure of its exact use. Since trouser belts were not in widespread use until after the Civil War, this buckle was most likely associated with some sort of equipment strap.

Table 6.3. Footwear parts.

| FIELD NO. | OBJECT | LEFT OR RIGHT | LENGTH (cm) | HEEL WIDTH (cm) | INSTEP WIDTH (cm) | BALL WIDTH (cm) | SOLE FASTENERS |
|----------------|------------------------------------|---------------|-------------|-----------------|-------------------|-----------------|---|
| Hunhou 99-053A | Sole of heel | Left | 30.3 | 8.3 | 6.7 | 9.4 | Double row wood pegs. Iron at heel. White metal at toe |
| Hunhou 99-053B | Sole without heel | Left | 29.7 | 7 | 5.6 | 9.3 | Double row wood pegs. Iron, wood, white metal at heel. Iron at toe. |
| Hunhou 99-053C | Upper fragment, heel area | n/a | n/a | n/a | n/a | n/a | n/a |
| Hunhou 99-054 | Substantial boot portion, no heel | Left | 29.8 | 7.3 | 5.1 | 8.8 | Double row wood pegs. Iron, wood at heel. Wood at toe |
| Hunhou 99-055 | Substantial boot/shoe, no heel | Right | 28.5 | 7.4 | 6.1 | 9.7 | Double row wood pegs. Iron at heel. White metal at toe. |
| Hunhou 99-056A | Sole with heel and heel upper | Left | 28.3 | 6.7 | 4.5 | 9.2 | Single row wood pegs. Wood, iron at heel. Double wood at toe, double row at instep. |
| Hunhou 99-056B | Substantial boot portion, squashed | Left | 28.7 | 7.2 | 6.2 | 9.7 | Double row wood pegs. Iron at heel. Two rows white metal at toe. |
| Hunhou 99-057 | Heel | n/a | n/a | 6.2 | n/a | n/a | Iron and zinc in heel. |
| Hunhou 99-058A | Forward half shoe/boot | Left? | (22.0 cm) | n/a | n/a | 10 | Double row wooden pegs. One row wood, one row white metal at toe. |
| Hunhou 99-058B | Upper fragment | n/a | n/a | n/a | n/a | n/a | n/a |
| Hunhou 99-059 | Boot leg fragment | n/a | n/a | n/a | n/a | n/a | n/a |



Figure 6.30. Photograph of crew members aboard USS *Chocktaw*, 1862–1865 (courtesy NHC).



Figure 6.31. Photograph of officers aboard USS *Monitor*, July 9, 1862 (courtesy NHC).

TOOLS

Seagoing vessels require constant maintenance. USS *Housatonic* would have carried a wide variety of tools for maintenance and repair to the vessel and its many systems. One of the main features in Trench 1 was a long iron “pipe” or “handle” that seemed to be attached to a concreted mass at one end. It was one of many concreted iron bar-like and plate-like objects in the trench, and was originally thought to be some part of the ship’s machinery. The pipe turned out to be a crowbar (Hunhou 99-038) 58.7 in. (149 cm) long and approximately 1.4 in. (3.5 cm) square. It has a square cross-section for approximately half its length 25.6 in. (65 cm), changing to a faceted section 8.7 in. (22 cm) long and then to a round section 24.4 in. (62 cm) long. The tip of the squared end is chisel-shaped. The tip of the rounded end is corroded so that the original shape is not preserved; it may have originally tapered to a point, as do modern crowbars. It is gently curved along its length (Figure 9.9).

This crowbar may have been part of the ship’s original tool assemblage, or may have been dropped on the site during the early salvage or dragging operations. The 1864 *Allowances* lists “Bars, Crow” in the carpenter’s department, with one assigned per ship.

Another possible tool is artifact Hunhou 99-060. This unidentified, poorly preserved copper-alloy object is one of several concretions found in the bulkhead area at the north end of Trench 2. It has an elongated teardrop shape, 2.2 in. (5.5 cm) long, with a flattened, narrow tip (Figure 6.32). It tapers and narrows from a circular cross-section at the wider end (0.3 in. [0.8 cm]), to square, then to a thin, rectangular section at its tip. It may be a small leatherworking tool, or perhaps an awl or a fid.

CONTAINERS

Containers of wood, glass and ceramic were required for storage of huge quantities of ammunition, food, medicine and other shipboard supplies. In the *Housatonic* artifact assemblage, wood box fragments and ceramic sherds are considered in the container category.



Figure 6.32. Hunhou 99-060 unidentified copper-alloy “teardrop.” NHC drawing by James Hunter.

CERAMIC VESSELS

Only two diagnostic ceramic sherds were found during excavations of the *Housatonic* wreck site, both among the concentration of artifacts in the bulkhead area in Trench 2. Since this area was below the sailors' mess and sleeping quarters, it is possible that these vessels were kitchen, medical or toiletry items that collapsed into the hold as the site deflated (Chapter 9). The base sherd (Hunhou 99-074) and rim sherd (Hunhou 99-075) of white, glazed ceramic have been identified as ironstone and whiteware, respectively (Chaney, personal communication 2002; Figures 6.33 and 9.16). Numerous tiny voids are visible in the white paste of both vessels under low magnification.

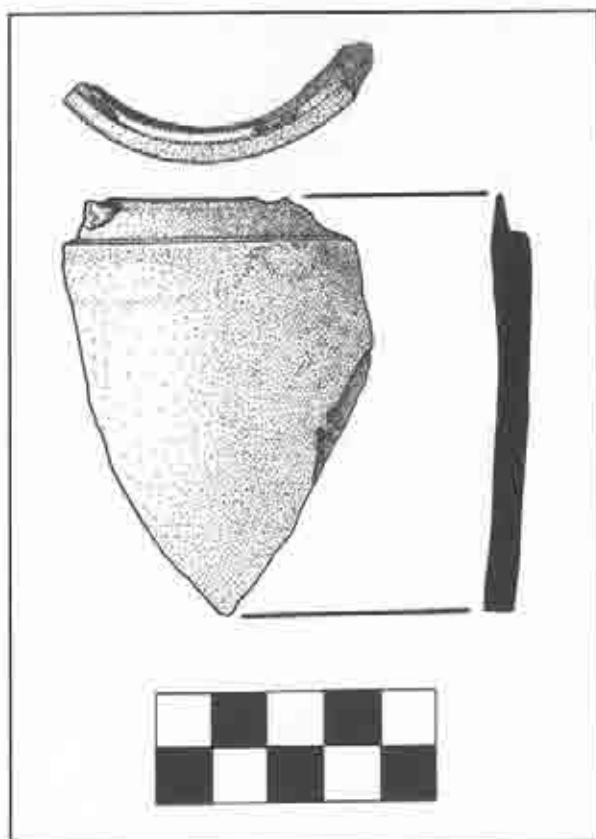


Figure 6.33. Hunhou 99-075 whiteware jar rim sherd. NHC drawing by James Hunter.

The oval ironstone base sherd Hunhou 99-074 has relief decoration in a foliate pattern and a vertical mold line in the area that would have been just below the handle. It appears to be part of a tureen and is typical of the white ironstone dinner services of the period (Wetherbee 1996; Boger 1971:163). No manufacturer's mark is present on the preserved area of the base. Ironstone china appears to have been in standard use on naval vessels of the period. Several intact pieces of white ironstone china were recovered from the wrecks of Union vessels USS *Tulip* (sunk 1864) and USS *Tecumseh* (sunk 1864), with marks indicating they were manufactured by at least five different British potteries (Thompson 1998:124–127; West 1997: Appendix I, p. 5–12; NHC artifact collections). Research into suppliers to the Boston Navy Yard may yield information on the origin of *Housatonic's* ironstone china.

Whiteware rim sherd Hunhou 99-075 appears to be from a small, straight-sided jar, originally 3 in. (7.5 cm) in diameter, that once had a lid. Pooled glaze on the recessed rim has a distinct blue tint, and a thicker band of blue-tinted glaze rings the jar just below the rim. A nearly identical jar, complete except for a lid, was excavated from the 1864 wreck of CSS *Alabama* and is called an "ointment jar" (NHC cat. no. 96-25-1). Shorter jars of the same style were recovered from the wrecks of CSS *Alabama* (NHC cat. no. 91-217-Y) and USS *Tulip* (NHC cat. no. 94-184-CX), none with maker's marks. Whiteware is similar to ironstone and was widely produced in American potteries from around 1860–1900 (Boger 1971:133).

A third ceramic sherd was found during conservation of concretion Hunhou 99-088. Included in the concretion was a small, undiagnostic, brown-slipped, glazed stoneware body sherd (Figure 6.34). This type of ceramic



Figure 6.34. Hunhou 99-088B brown-slipped stoneware sherd. WLCC photo by Shea McLean.

frequently exhibits a brown or other dark-colored slip on one or both surfaces, while the glaze on the exterior is typically a clear salt or lead glaze. Brown-slipped stoneware most frequently appears as kitchen/utility wares such as jugs, large crocks and storage containers (Hume 1969:98–101).

WOOD BOXES

Several fragments of thin, softwood planks were found on the hard-packed coal surface of Trench 1, approximately 12 in. (30 cm) below the level of the iron crowbar. They have dovetail tenons with small rectangular nail holes in the tenons. Fragments from Hunhou 99-014 and 99-008, both $\frac{1}{2}$ in. (1.3–1.4 cm) thick, join each other. Plank Hunhou 99-021 (Fig. 9.14), thicker than the other pieces (1 in. [2.5 cm]), also has four blind screw holes in the plank surface (0.2 in. [0.4–0.6 cm] diameter). These fragments appear to be parts of one or two boxes, perhaps storage boxes for fuses or supplies.

WRITING IMPLEMENTS

Writing was a regular activity on board ships, from the captain writing in his log, to the sailor writing letters home during periods of rest. The 1864 *Allowances* lists a variety of stationery items carried on Navy ships: in the Paymaster's department alone are pens, pencils, penholders, quills, letter paper, envelopes, inkstands, ink (black and carmine), rules, mucilage and "Tape, Red" (Navy Department 1865:144). Items relating to writing that have been found on contemporary shipwreck sites include inkwells found on the 1864 site of USS *Tulip* (Thompson 1998:142), and three short pencils found with the crew inside *H.L. Hunley* (catalog nos. HL1097, 1.1 in. [2.9 cm] long, HL1693, 3.9 in. [9.8 cm] long, and HL2106, 2.2 in. [5.7 cm] long).

One half of a long writing pencil (Hunhou 99-076) was found amongst the shoes and other items immediately adjacent to the wooden bulkhead in Trench 2 on the *Housatonic* site. It is 6.8 in. (17.3 cm) long, made of wood and what is assumed to be graphite (the "lead" writing medium). The full length of the pencil is preserved and the writing tip is sharpened. The distal end has a central protrusion that may have once held a cap, and the graphite rod protrudes slightly beyond the wood (Figures 6.35 and 9.17). The pencil's original diameter was 0.3 in. (0.75 cm); the graphite diameter is 0.06 in. (0.15 cm).

Impressed lettering J. W. GUTTK_E_HT NO.2 on the distal end of the pencil identifies it as manufactured by the Guttnecht company based in Stein, near Nuremberg, Germany. In operation since the 1760s, the company was sold in 1865 and acquired by A.W. Faber in 1907 (Suppa, personal communication 2002). Traces of paint appear to be preserved on the surface of the wood.

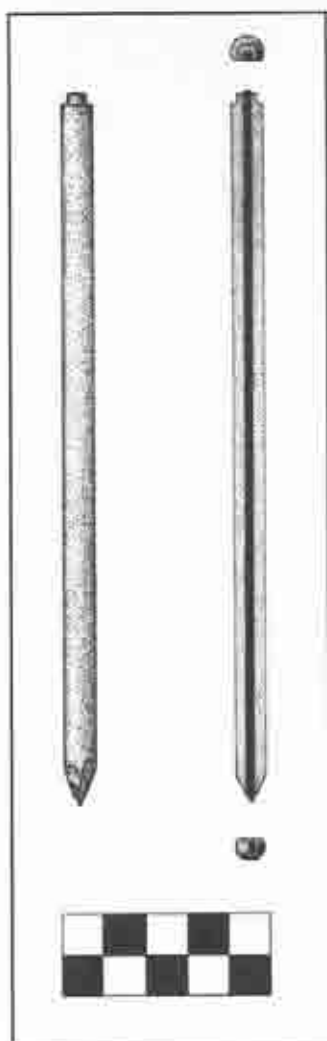


Figure 6.35. Hunhou 99-076 writing pencil. NHC drawing by James Hunter.

The pencil "lead" may be graphite, or a mixture of clay and graphite fired to hardness. The survival of only half the diameter of the pencil is not surprising considering the manufacturing process: the graphite rod was inserted into a grooved wood form, and then another wood portion glued onto it to form the full cylindrical pencil (Petroski 1990). Pencils are listed in the 1864 *Allowances* in the carpenter, medical, paymaster and miscellaneous departments, where they are described as "Pencils, lead, one-quarter blue and red",

"Pencils, camel's hair, assorted" and "Pencils, slate" (Navy Department 1865:77, 130, 144, 150).

WEIGHTS

Two small lead weights were found on the site and are presumed to be fishing weights. Lead fishing weights have been used for millennia and are found in all sorts of different shapes and sizes that are not necessarily indicative of their date. It is difficult to determine if the weights found deep within the *Housatonic* site belonged to the crew or made their way there as a result of more recent activity.

Weight (Figure 6.36) is a solid cylinder topped with a thin brass loop handle, with a total height of 3.2 in. (8.1 cm), diameter of 0.75 in. (1.9 cm) and weight of 7.7 oz (191.3 g). It was recovered from the north end of Trench 1 along with an artillery fuse (Hunhou 99-011) while clearing overburden and backfilled sediment from on top of the hard-packed coal and concretion surface.

Another weight (Figure 6.37) was found in Trench 3 near the deposit of unidentified pipe-like features. It is roughly conical, with a suspension hole (0.2 in. [0.5 cm]) at the thin end, and a small hollow cavity in the base. Its overall length is 2 in. (5.0 cm), maximum diameter 1.1 in. (2.7 cm) and weight 6.2 oz (176.2 g).

Weights, scales and a steelyard are listed in the 1864 *Allowances* in the medical, paymaster's and steward's departments (in one case specified as zinc), but it is expected that a weight from one of these sets might have been of finer quality, and marked with its value. Neither of the excavated weights is marked.

MISCELLANEOUS

There are several unidentified or uncategorized artifacts from the excavation of the *Housatonic* site.



Figure 6.36. Hunhou 99-012 lead weight. NHC drawing by James Hunter.

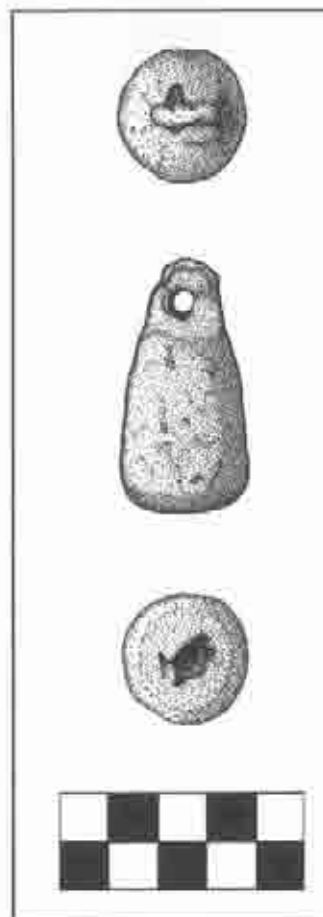


Figure 6.37. Hunhou 99-082 lead weight. NHC drawing by James Hunter.

WOOD FRAGMENTS

Several wood fragments were recovered from the site, most of them from Trench 1. In some cases, it was not clear if a wood fragment was intrusive, carried into the trenches by water movement or was original to the excavation context. Most pieces are of unknown function.

A sample (Hunhou 99-024) was taken from the large log protruding into the southwest corner of Trench 1 at a level approximately 40 in. (1 m) above the coal surface and 40 in. (1 m) below the seafloor. The wood is a softwood in good condition except for extensive channeling by marine borers. Based on its position above

the level of cultural material, this log may not be associated with the shipwreck.

Three more wood fragments came from the same area as the log Hunhou 99-024 in the south end of Trench 1. Thin, softwood plank fragment (Hunhou 99-029) has one chamfered end and a square mortise in one edge, filled with the remains of a 0.3 in. (0.8 cm) square coak or peg. Like wood fragments Hunhou 99-032 and 99-035, near which it was found, it is not clear if this wood is intrusive or not. It may be part of a barrel cover. One plank (Hunhou 99-032) is a short, thick, rectangular softwood plank fragment with finished ends, but broken edges, and three fastener holes (0.2

in. [0.6 cm] diameter). Another plank (Hunhou 99-035) is a 0.9 in. (2.2 cm) thick softwood plank with an irregular tenon at one corner. One face has a thin coating of an unidentified black substance.

Four other wood fragments are more clearly associated with the shipwreck. A slightly curved timber with a joinery scarf at one end was found protruding from the hard-packed coal surface at the bottom of Trench 1, at the south end. The timber could not be fully excavated, but a sample (Hunhou 99-045) was retrieved and found to be a softwood, probably pine, based on the strong resinous smell. The timber was approximately 7 in. (18 cm) wide and 2–3 in. (5–7 cm) thick; it continued into the hard-packed matrix, so a full length could not be determined. The protruding end had a flat scarf or lap-joint 2.4 in. (6 cm) long and 0.8 in. (2 cm) thick. This timber may have been part of a piece of furniture or deck structure.

A thick softwood timber (Hunhou 99-036A) is heavily degraded and iron-stained, with only one original face preserved. It has one large (0.5 in. [1.2 cm]) square fastener hole in this face; the other end of the fastener hole is plugged by a treenail or circular peg 1.2 in. (3 cm) in diameter and 0.7 in. (1.8 cm) thick (as determined from an x-radiograph). The plugged end was the head end of the fastener. The timber was found loose adjacent to the crowbar, in the area in which box fragments (Hunhou 99-008 and 99-014) were found.

A small, hardwood log (Hunhou 99-036B) was found embedded in the hard-packed matrix adjacent to and partly beneath pistol Hunhou 99-042. It has one cut end, which was buried in the coal matrix; the other end is deteriorated. The log is 15.2 in. (38.5 cm) long with an average diameter of 2.4 in. (6.0 cm). This might have been a piece of fuel wood, which was sometimes substituted for coal during coal shortages (Allston 1995:83).

The 1864 *Allowances* lists “Wood, seasoned and clean.... As may be required and can be conveniently stowed. Coal should be used instead, when practicable” (Navy Department 1865:18).

A softwood, frame-like timber (Hunhou 99-068) was found in the sediment surrounding the water tanks in Trench 2, but not directly associated with the wooden structure in the NE corner of that trench. It has portions of three sides preserved and is heavily riddled with marine borer channels. A 0.4 in. (0.9 cm) square fastener hole in the best-preserved surface is 2.3 in. (5.8 cm) deep; the chisel-tipped fastener that filled it was iron, as indicated by heavy iron staining around the hole.

ANIMAL BONE

A fragment of an animal rib bone was found in Trench 1 in the sediment near timber Hunhou 99-045. It has one flat, cut end with clear parallel butchering marks; the other end is broken. If the bone is part of the ship's assemblage and not an intrusive item, it may represent fresh meat that, along with fresh vegetables, was delivered to blockading vessels by refrigerated ships during the Civil War (Allston 1995:81). A portion of sternal cartilage, probably from a cow, was also found in the sediment surrounding *H.L. Hunley* (Murphy et al. 1998:100–101).

COPPER-ALLOY STRAP

A thin, narrow, copper-alloy strap 8.1 in. (20.5 cm) long was found protruding from a concretion mass (Hunhou 99-044) that also included a fragment of leather and an undiagnostic flat iron fragment. It was found in the same area as stock cap Hunhou 99-041, brass tube Hunhou 99-034 and other small items near the crowbar, on the hard-packed surface at the

bottom of Trench I. The strap has one hole (0.3 in. [0.7 cm]) at each end, and in the center, a 0.8 in. (1.9 cm) diameter circular ridge of lead-containing metal, perhaps solder. This area

appears to have had something circular attached to it, now lost (Figure 6.38). The function of this object remains unknown. It may be a fitting for a shoe or boot, or perhaps a strap to support piping.



Figure 6.38. Hunhou 99-044A copper-alloy strap with rondel. NHC photo by Claire Peachey.

CHAPTER 7

Artifact Conservation

Shea W. McLean and Claire P. Peachey

Objects recovered from the *Housatonic* site are made from a wide variety of materials and have required different levels of field and laboratory conservation.

FIELD CONSERVATION

Conservation in the field consisted primarily of keeping the objects constantly wet, transporting objects back to land safely, storing them in stabilizing solutions and recording them as soon as possible after excavation.

Lack of space aboard the dive boat and the labor-intensive nature of the diving activities did not allow any work to be carried out on the artifacts immediately upon excavation. Objects were simply placed in a container of seawater, assigned a field number and given a Tyvek (spun-bonded polyolefin) tag for identification. The artifact container was a sturdy, lidded plastic box, well-labeled to avoid any confusion with containers of dive equipment.

At the end of each diving day, the artifacts were transported by boat and automobile to the

project headquarters where they were sketched at 1:1 scale on mylar drafting film, and cataloged in detail. On nondiving days, all were photographed with color slide and black-and-white film. Some objects were placed into tap water or into deionized water produced from tap water with a small Barnstead deionizing column.

Some artifacts were fully desalinated and dried by the end of the field project. Others were only minimally brushed to remove excess mud. No hard accretions were removed from objects, and no concretion masses were broken open during this phase of the work. The Medical University of South Carolina (MUSC) x-rayed many of the objects during our field season, greatly aiding in their identification.

For transportation back to the Naval Historical Center (NHC) conservation laboratory in Washington, DC, by automobile, the objects were wrapped in polyethylene foam. As necessary, sealed containers were completely filled with water, while open containers were emptied of water to avoid movement during transport (Leskard 1987).

LABORATORY CONSERVATION

In the NHC lab, all organic artifacts were placed in a refrigerator to minimize light and microbial activity. Concretions displaying iron oxidation were placed in 1% sodium hydroxide solutions, while those with no iron oxidation were placed in 1.25% sodium carbonate solutions or water. Some copper-alloy objects and corroding, mixed-material objects were also placed in 1.25% sodium carbonate solutions. These alkaline solutions minimize corrosion of the metals (Pearson 1987:111).

Artifact conservation treatments are summarized below, grouped according to material or by individual object, as appropriate. Full treatment reports are on file at the NHC.

Most objects were partially to completely covered in extremely hard, adherent concretion, a cement-like combination of sediment, marine shells, corrosion products and precipitated calcium carbonate. The concretion sometimes included bits of coal, glass, slag, ceramic and wood. Mechanical (nonchemical) methods of concretion removal included scalpel, dental pick, hammer and chisel, Vibro-Graver (engraving needle), air scribe (pneumatic needle) and Cavitron (dental ultrasonic descaler). In a few cases when hand methods were ineffective or damaging, chemical methods were also used to remove accretions.

In all cases, the objective of conservation treatment was to identify and stabilize the objects, and reveal their technological details. As is frequently the case in archeological conservation, aesthetic considerations were not primary, but artifacts were reshaped or reconstructed when desirable or necessary.

CERAMIC

The two white, glazed ceramic sherds (Hunhou 99-074 and 99-075) had areas of black

staining commonly seen on ceramics buried in anaerobic environments or in proximity to metals. This type of black staining is difficult to identify without chemical analysis; it is usually described as being of organic or metal origin, and in some lead-glazed ceramics such as these, has been identified as lead sulfide (Tennent et al. 1996). Treatment with hydrogen peroxide has been shown to be effective at removing or lessening organic and lead sulfide stains, while EDTA (ethylene diamine tetra-acetic acid) can remove metal-based stains (Tennent et al. 1996; Buys and Oakley 1993:91-95). The staining on the *Housatonic* sherds was partially removed by immersions in hydrogen peroxide or 5% disodium EDTA solutions. Complete stain removal was not attempted, to avoid damaging the ceramic fabric, particularly with EDTA. The development of a faint orange coloration in place of the black coloration on Hunhou 99-075 may be the lead sulfate described in Tennent et al. (1996:184, 186). After thorough rinsing in deionized water baths, the sherds were slowly air dried.

COAL, BONE AND GLASS

Coal, bone (Hunhou 99-040) and glass (Hunhou 99-065) were in good condition and mostly free of accretions. They were simply desalinated in baths of deionized water, sometimes preceded by seawater/tapwater and tapwater/deionized water mixes, to avoid any possible effects of osmotic pressure on the porous materials (Pearson 1987:114-115). Bone and glass were given a final bath of 1:2 ethanol:deionized water before slow-drying in a closed container. A splintering area of the bone was later adhered with 30% Acryloid B72 (acrylic copolymer adhesive) in acetone. The glass has a faintly iridescent surface layer after drying, typical of deteriorated archeological glass.

RUBBER RING

Upon excavation, some of the outer layers of the rubber ring (Hunhou 99-018) were torn and loose, and it was coated with mud and patches of encrustation. It was gently brushed to remove mud, then placed in baths of tap water followed by changes of deionized water in the field. It had a faintly unpleasant, unidentifiable smell. It began undergoing changes soon after it was excavated and was considered a treatment priority. The loose, outer delaminating layers began expanding and curling, so a jacket of fine nylon netting was sewn loosely around the surface with fine nylon fishing line. One small fragment of rubber was removed to test the suitability of stabilizing the artifact by air-drying; this test produced good results.

Once in the laboratory, further examination showed that the object had remains of loose fibers, so a small piece was immersed in 10% polyethylene glycol (PEG) 400 solution and air dried. This produced good results, so the ring was immersed in 10% PEG 400 for 3½ months and air dried over several months, all in a refrigerator to prevent microbial growth and exclude light. Upon drying, the delaminating layers returned to their original configuration. The object retains its unpleasant smell, and during storage, areas of its surface have become gummy, while others are more brittle. Rubber is difficult to stabilize and is known to degrade readily in the presence of oxygen and light. Therefore, the object will be placed in a sealed container with an oxygen scavenger, both to create a low-oxygen environment and to absorb any possibly harmful offgassing products (Loadman 1993; Clavir 1982; Shashoua and Thomsen 1993).

LEATHER BOOT FRAGMENTS

Treatment of the leather artifacts depended very much on their condition upon recovery,

which varied widely. Some leather was thick and robust, while other pieces were thin, delaminating, torn, encrusted and crushed out of shape. In the field, objects were placed in individual containers of tap water, followed by deionized water. Most objects were not handled, except for photography, in order to minimize damage. After transport to the NHC lab, they were stored in a refrigerator until active treatment began (English Heritage 1995). Some of the water storage baths turned dark brown, possibly due to leaching of tannates (Ogilvie and Sully 1997:592); all the leather is likely to be vegetable-tanned.

Mud was removed by a combination of techniques: pushed off with fingers, squirted off with water squirt bottles, or brushed off, sometimes with the help of a few drops of nonionic detergent to loosen adherent sediment. A robust heel piece was put into an ultrasonic bath with water and a few drops of nonionic detergent for a few seconds to help remove ingrained silt that was visible under low magnification. If metal staining was present, as it usually was around corroded metal nails at the heel and toe, this staining was lessened by local poulticing with, or sometimes brief immersion in, a solution of 5% disodium EDTA, with varying effectiveness (Hovmand and Jones 2001).

After mud and metal residues were removed, the shoes were immersed in a solution of either 15–30% PEG 400 or 25% glycerol for varying periods (Ganiaris et al. 1982). The artifacts were kept in a refrigerator during these treatments.

After PEG or glycerol immersion, leather artifacts were placed in a domestic chest freezer at –27C on a foam covered acid-free board support. If any reshaping was necessary or indeed possible, this was achieved through the use of polyethylene foam inserts, Tyvek ribbon strips, Berna clamps and polyethylene “cling film” wraps before being placed in the freezer. After freezing, objects were vacuum freeze-

dried, then slowly acclimatized to room temperature (Wills 2001; Bonnot-Diconne et al. 1999; Pearson 1987).

A few leather shoes and fragments still await full treatment. Some pieces will be air-dried after PEG impregnation, rather than freeze-dried, to observe differences in the results. Most dried pieces will require significant repair of torn and delaminating areas and inserts for support. Thin, flat, fragile boot leg fragment Hunhou 99-059 has been stored in a custom-made window support that allows both sides of the leather to be viewed without handling the leather at all; this is based on flat textile and paper support strategies (Commoner 1992; Northeast Document Conservation Center 1992).

PENCIL

The wood pencil (Hunhou 99-076) was a uniform brown-black color when excavated, lightly encrusted and appeared to be in good condition. It was stored in a mixture of tap water and seawater in the field, then in deionized water in the lab. Oxidation of iron corrosion products turned the dark brown-black surface orange in places. Treatment in the lab began with a test for the presence of lead in the "writing lead," using potassium iodide and nitric acid; the result was negative, as expected. It was decided not to remove a sample for wood identification at that time.

During investigation, it was found that traces of paint remain on the surface of the pencil. Also, impressed lettering was revealed when light encrustations were removed with a scalpel. Poultices of 5% disodium EDTA solution were applied to iron-stained areas. After a test to determine solubility of the paint, the pencil was immersed in a solution of 5% PEG 400, increased to 10% after several weeks. This low concentration of PEG was used to avoid dissolution of the paint (Cook, personal communication 2002). The pencil was then

vacuum freeze-dried, with good results. The wood has lightened in color, so that a general wood identification without sampling may now be possible.

WOOD

Some of the excavated wood items are fragments with finished edges and diagnostic features, while others appear not to be man-made. Many pieces may be intrusive to the site, carried into the excavation areas by water movement, as happened regularly during excavation of the nearby *Hunley* site. No complete objects were found. Most pieces are softwoods.

Wood objects were stored in a mixture of seawater and tap water mix in the field. Most pieces were in good condition, with soft surfaces and robust interiors, determined by insertion of a needle into the surface. A few pieces were heavily damaged and weakened by marine borers, with large, long tunnels lined with thin calcium carbonate crusts and filled with both soft and compact sediment-like debris. Some pieces were partially covered in tenacious concretion, and others were iron stained.

In the laboratory, the wood objects were desalinated in changes of deionized water. Mud and sediment were cleaned off with fingers, brushes, squirt-bottles and running water. Sediment in the marine borer channels was removed with a wooden stick, pulsating water jet and running water.

Most pieces were then treated by immersion in 20% PEG 400 solution for several months, some at room temperature, some in a refrigerator. PEG 3350 (5% by weight of the total solution volume) was then added to some PEG 400 baths to provide further stabilization of more heavily deteriorated wood. After PEG immersion, the wood was rinsed well, wrapped in polyethylene "cling wrap," frozen in a

domestic chest freezer at -27°C , and vacuum freeze-dried (Pearson 1987; Bonnot-Diconne et al. 1999).

Wood pieces that were heavily encrusted or iron-stained were pretreated with a variety of methods, some experimental (and not all recommended), as many of the wood pieces were nondiagnostic. Citric acid, acetic acid, hydrochloric acid, ammonium citrate, sodium dithionite and an ultrasonic descaler were tried on different pieces to test the relative effectiveness of these reagents and methods in removing concretion and iron staining. In most cases, iron staining could not be fully removed, and concretion removal by mechanical methods resulted in some damage to the wood surface. Acids, chelating agents, and reducing agents are effective at removing some stains and crusts, but their effects on wood itself have not been fully evaluated.

COPPER ALLOYS

Copper-alloy objects were preserved in a variety of conditions. Some were covered in dark purple-black corrosion crusts, while others were raised from the seabed with bright coppery and brassy metal surfaces, completely free of accretions. All were placed in tap water followed by deionized water in the field. In the laboratory, some were placed in 1.25% sodium carbonate storage solutions until active treatment began. Mechanical and/or chemical (local application of 5% citric or 10% formic acids) treatment strategies were followed, as appropriate for each object. After removal of accretions, most objects were immersed in a solution of 3% benzotriazole (BTA) in ethanol to inhibit corrosion (Brostoff 1997), dried, then coated with 3–5% Acryloid B72 in acetone, sometimes followed by a light brush application of microcrystalline wax in mineral spirits.

Stock cap Hunhou 99-041 is composed of wood and brass that could not be separated for

treatment. An alcohol dehydration method was chosen as the treatment for the wood (Brybaert 1999; Pearson 1987:166), to avoid any corrosion of the copper alloy that can sometimes occur in PEG solutions. The object was immersed in water baths containing progressively more ethanol, and in several baths of 100% ethanol. It was very slowly dried in a closed container, with some wood shrinkage occurring. The wood was consolidated with 5% Acryloid B72 in an acetone/ethanol mixture, and the metal was coated with 5% Acryloid B72 in acetone.

Brass trigger guard Hunhou 99-025 was found covered in extremely tenacious marine concretion, which required several methods to remove. After unsuccessfully attempting to remove some concretion with a scalpel, the object was put into an ultrasonic descaler for two periods of one minute each to soften much of the adherent mud. It was immersed in 7% disodium EDTA to soften the concretion. After less than one hour, blue coloration indicated that copper was going into the solution, so this was discontinued; still the accretion had not softened at all. A Cavitron ultrasonic descaler was ineffective. The object was put into electrolytic reduction in an attempt to loosen the surface crusts through the evolution of hydrogen from the metal surface (Pearson 1987:237–238, 225); a sodium carbonate electrolyte and steel anode were used, with the voltage and current at the lowest level at which bubbles began to evolve from the surface (approximately 3.5V and 0.25 amps). This did help to dislodge some of the crusts, but after a brief period it also appeared to cause pitting of the exposed metal, so was discontinued. Remaining crusts were removed with a scalpel, hammer and chisel. The iron trigger of this object (and of trigger guard Hunhou 99-062) was fully corroded away, but may be preserved as a mold in the surrounding concretion; the concretion in the trigger area was broken off as a mass so that the corrosion void

can be cleaned and cast with epoxy as described below for iron objects.

During water storage in the laboratory, some copper-alloy objects lightly corroded. Most common was the formation of a hazy blue-grey corrosion product, as yet unidentified. Brass tube Hunhou 99-034 developed this blue-grey haze and small orange pustules likely to be copper oxide.

Socket Hunhou 99-067 developed bright orange pustules, mainly along cracks in the corrosion layers. These caused some areas of the thin, black, already fragile and patchy corrosion layer that was preserved directly over the metal core to buckle and flake. Since the brassy-colored metal core below does not preserve the fine machining lines preserved in the thin black corrosion, loss of this corrosion layer would mean loss of diagnostic technological details. This object is an excellent example of the importance of preserving corrosion products on metal objects, and choosing conservation treatments that will not indiscriminately strip, reduce or otherwise alter them. Flaking areas were stabilized by wicking in Acrysol WS-24 water-based acrylic consolidant. Once dry, this object was fully consolidated with dilute Acryloid B72 in acetone.

The copper-alloy bolts were all preserved with a bright, pitted, fissured, etched metal surface, sometimes covered in tenacious concretion. These objects also underwent changes during wet storage, acquiring both dark black and hazy pale blue colorations. These unwelcome corrosion patinas were removed in some cases by swabbing, brushing or very brief immersion in a solution of 5% citric acid (Pearson 1987:234), a technique not normally necessary, but known to result in a metallic surface similar to the bolts' original appearance upon excavation. Two bolts were treated with alkaline dithionite to even out their altered

coloration acquired during wet storage (Fox 1995).

These changes illustrate the importance of avoiding prolonged wet storage of artifacts, even those that appear stable. Desalination in tap water rather than deionized water may have minimized some corrosion, as copper alloys are known to corrode in deionized water (Pearson 1987:235). The best solution, however, is immediate desalination and drying of the objects.

The sword holder (Hunhou 99-090) was desalinated and dried in the field, retaining its bright yellow coloration. Tack Hunhou 99-093 with a dark yellow-brown surface color was treated in the same way. They were later coated with 5% Acryloid B72 in acetone to protect the surface.

LEAD

Lead objects were desalinated in changes of tap water in the field. After brushing to remove white corrosion spots, they were dried in the field. In the laboratory, they were coated with 3–5% Acryloid B72 in acetone and then microcrystalline wax in mineral spirits, by brush. Lead sheet 99-052 was dried and not coated. It will be monitored in storage for any corrosion development. To prevent excess handling of this object, which is weak and heavy, a rigid acid-free board support was constructed for it.

ZINC ARTILLERY FUSES

Upon excavation, the material composition of these objects was not immediately clear. The artifacts were heavy, with pink-grey and brown corrosion, and fissured like corroded lead. Most were so heavily encrusted that few features were visible. One fuse was later analyzed at the Naval Research Lab and found to be zinc (Elam and Karol, personal communication 1999), so it

has been assumed that the other five are also composed of zinc, as expected for this type of fuse (Chapter 6). One fuse (Hunhou 99-026) has what appears to be a rubber gasket beneath its head or flange.

X-radiography shows that the metal of each fuse is highly corroded, and in the case of one (Hunhou 99-064), may no longer retain any distinguishable surface beneath the heavy accretions. The dense insert visible in the radiographs of each fuse is probably copper alloy, based on historic descriptions.

The zinc artillery fuses were handled minimally due to their potentially explosive nature. In the laboratory, one was partially cleaned with a scalpel to reveal surface features, but this could not be continued because of the extreme hardness of the concretion. All fuses are in the hands of Navy explosive ordnance personnel for "inerting." The fuse shafts will be drilled out, then flushed with water to remove any explosive material (probably black powder) that may remain. Following this treatment, they will be returned to the conservation lab to be mechanically cleaned to reveal their surfaces.

IRON CONCRETIONS

Iron concretion masses were stored in either water or dilute sodium carbonate solutions in the field, then in water, 1% sodium hydroxide, or 1.25% sodium carbonate solutions in the lab. Those that had not been x-rayed at MUSC were x-rayed at the Maryland Archaeological Conservation Laboratory, St. Leonard, MD. Eight of the concretions were redirected to the Warren Lasch Conservation Center (WLCC) in Charleston, SC, for treatment. All were amorphous masses with few external clues as to what was contained inside. Simple tests with a magnet, or the development of iron corrosion staining sometimes helped to indicate the presence of iron.

X-radiography revealed that all encrusted objects contained remains of iron objects. Many also contained other cultural fragments such as glass, wood, hemp, coal, brass and pottery. Some had little or no iron metal remaining, so were nothing more than hollow molds of the completely corroded objects; others contained portions of the original iron metal. Through consultation of the radiograph, hollow molds were carefully opened in strategic locations by controlled breaking, or by removing some of the accretion, then were cleaned out and poured with Hysol ES 4412 epoxy. After the liquid epoxy had set, the rest of the surrounding accretions were removed with an air scribe or hammer and chisel to reveal the epoxy replica of the iron object, and any other incorporated artifact material. When possible, wood fragments were left attached to the epoxy casts and conserved as a whole. All other cultural fragments were removed for separate stabilization.

As previously discussed in Chapter 6, most of the iron features inside the concretions were fragmentary fasteners of different sizes and shapes. Other objects found within the concretions include brass pin Hunhou 99-066B, copper-alloy tack Hunhou 99-081B and stoneware sherd Hunhou 99-088B.

Concretion Hunhou 99-089 was particularly complex. X-radiographs clearly showed the outline of an iron fastener and multiple wood fragments inside the concretion. The low radiographic density of the fastener suggested that the iron metal had completely corroded away. To cast the hollow mold, the concretion was broken in half at the center and poured with epoxy. A metal rod was inserted into the two halves within the epoxy to provide stability for the long cast (51 cm [over 20 in.]).

As the accretions were cleaned off the cast, a wooden plug was found capping the fastener's head, and a yellowish-white caulking was found

around the head. The caulking lines up directly with a radio-dense lens seen in the x-ray image, so is thought to be lead based. Two oakum gaskets were found separating three distinct sections of wood along the bolt shaft. The dense wood, not yet identified, is riddled with marine borer channels.

Two concretion masses did not contain iron fasteners. The radiograph of concretion Hunhou 99-086 showed it to be several links of iron chain, but with no iron metal remaining. The voids in this complex concretion may be cast with epoxy in the future to create a replica of the original chain. However, the information gained from the clear x-radiograph already allows interpretation of this object (Chapter 6).

It was difficult to get a clear radiograph of concretion Hunhou 99-078 because of its high density and thick buildup of accretions. Further radiography and consultation indicated it was simply solid iron round shot. The heavy concretion was easily removed with a few blows with a hammer and chisel to reveal a perfectly preserved piece of cast iron round shot.

With well-preserved iron, the treatment objective was to remove as many chloride ions as possible, as these stimulate corrosion in the presence of moisture and oxygen. While many treatment options are available (Pearson 1987; Selwyn and Logan 1993; Watkinson 1996), the technique chosen was to remove soluble chlorides by diffusion, using an alkaline solution rather than water, to minimize corrosion through the long process (Pearson 1987:221–222; Watkinson 1982:28, 39; Argyropoulos et al. 1997). The shot was immersed in changes of 1% sodium hydroxide solution until chloride ion measurements were constant and low, then rinsed in heated water baths until pH was neutral. It was then immersed in ethanol for several hours and liberally brushed with acetone to remove much of the water. To protect the surface, several coats of 5% tannic acid solution were applied (Canadian Conservation Institute 1997).

After allowing it to fully dry, the surface was coated with 5% Acryloid B72 in acetone, followed by microcrystalline wax in mineral spirits, all applied by brush.

IRON CROWBAR

Iron crowbar Hunhou 99-038 was too long for any field storage containers, so was wrapped in polyethylene foam and several layers of plastic sheeting to keep it wet during field storage. At the laboratory it was immersed in 1% sodium hydroxide solution to prevent further corrosion, particularly at one end where the protective concretion crust was broken off, exposing the iron metal.

This object was covered in a thick, even layer of hard marine concretion, which was removed with hammer, chisel and air scribe to reveal a relatively even, soft black corrosion surface preserving the original shape. Some areas of this soft corrosion surface are less stable and have cleaved off to reveal the typical fissured, corroded iron core below. Treatment is still in progress. After removal of chloride ions through soaks in 1% sodium hydroxide solutions, it will be rinsed, dried and coated as described above for the iron shot.

STORAGE AND DISPLAY

Treated, dry objects are stored in acid-free, archival quality materials inside wood or metal cabinets in the NHC lab. For example, each object has been placed in an open box made of acid-free corrugated blueboard joined with hot-melt adhesive and lined with polyethylene foam and acid-free tissue. Each box is protected by a clear polyethylene bag or sheet to keep out dust. Each is well labeled on the exterior, with the artifact number and any special artifact handling instructions. Final storage is designed to allow minimal handling but maximum access to the objects. Conditions of light, temperature and

relative humidity are kept constant inside the storage cabinets. Extremes and fluctuations in relative humidity in particular can be damaging to treated artifacts. Following conservation and study, most objects will be placed on public display.

SUPPLIERS

Acryloid B72, Acrysol WS-24, Tyvek products, nonionic detergent: Conservation Resources (VA)

Air Scribe (pneumatic chisel): Chicago Pneumatic (NY)

Berna clamps, microcrystalline wax: Talas (NY)

Cavitron (ultrasonic descaler): Dentsply (PA)

Deionizing column: Barnstead/Thermolyne Corporation (IA)

Hysol epoxy: Dexter Corporation (NY)

Plastic storage boxes: Lab Safety Supply, Wal-Mart (WI)

Polyethylene foam, acid-free tissue, acid-free blueboard: University Products (MA); Alexandria Packaging (VA); Gaylord Brothers (NY)

Polyethylene glycol (PEG)/Dow Chemical Company (MI)

Reagent chemicals: Fisher Scientific (PA)

Vibro-Graver (electric engraver): Burgess Products (NY)



CHAPTER 8

Environmental Context—A Multidisciplinary Approach

David L. Conlin

INTRODUCTION

In broad terms, four sets of interrelated variables—geological, oceanographic, meteorological and human—have combined to shape the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site after its formation in 1864. Human impact on the site, primarily salvage but also alternation of coastal sediment pathways, have been mentioned in Chapter 2 and will be discussed further below. This chapter discusses natural forces operating on the remains of *Housatonic*, *Hunley* and other archeological materials related to these two vessels. Delineation of natural and cultural site formation processes, an important first step in any archeological interpretation, was a fundamental element of the *Housatonic* research design (Chapter 3).

Environmental variables affecting the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site interact across a wide range of time and space ranging from minutes to centuries and from inches to miles. For analytical purposes it

is useful to separate these three sets of variables into regional and site specific processes, though in reality the level at which these forces operate spans a continuum that shades more or less seamlessly from one level to another.

BACKGROUND

South Carolina is the smallest of the southeastern United States and has an area of 80,500 km² (31,113 mi.²) and a coastline 294 km (183 mi.) long (Figure 8.1). The state lies between 83°30' and 78°30' west longitude and 35°15' and 32°00' north latitude. Its relatively low latitude, combined with the strong regional effects of the Atlantic Ocean in general, and the Gulf Stream in particular, lead to a mild temperate to subtropical climate with cool rainy winters and hot humid summers—particularly on the coastal margin.

Geographically the state is divisible into five principal physiographic zones: the rolling Blue Ridge Mountains, a part of the Appalachian chain, in the northwest; Piedmont, characterized

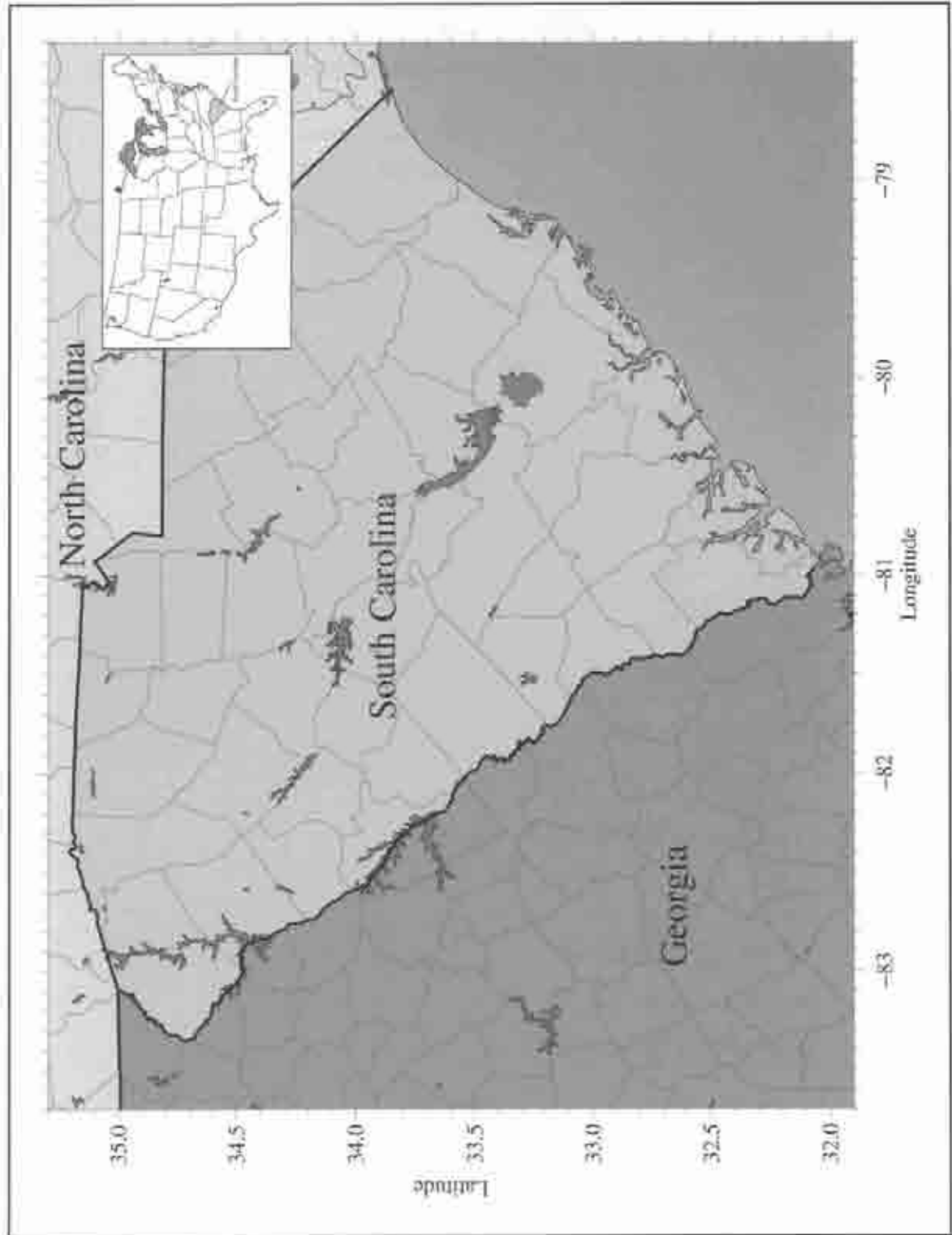


Figure 8.1. South Carolina.

by isolated, older mountains east of the Blue Ridge chain; Sandhills, a hilly unconnected set of sedimentary dunes deposited during the Miocene Epoch; the Coastal Plain characterized by large flood plains, swamps and rivers; and the Coastal Zone extending approximately 16 km (10 mi.) inland (Figure 8.2). Of the five divisions, the Coastal Zone determines the environmental context of the *H.L. Hunley/US Navy Housatonic Naval Engagement Site*.

The Coastal Zone is comprised of a backwater of savannahs, brackish swamps, coastal inlets and wetlands fronted by a sandy coastline that is divisible into the 96 km (60 mi.) arc of the Grand Strand that runs from the North Carolina border south to Winyah Bay; 28 km (18 mi.) of the Santee River Delta; and 168 km (105 mi.) of sea islands that stretch south to the Georgia border. The *H.L. Hunley/US Navy Housatonic Naval Engagement Site* lies offshore of the sea island complex.

REGIONAL-LEVEL PROCESSES

GEOLOGY

Regional Geology and Geological History

The South Carolina sea island complex is part of the larger coastal plain that reaches from south Texas through Florida to northern New Jersey (Figure 8.3). The coastal plain is composed mainly of marine sedimentary deposits from the Late Cretaceous to Holocene partially overlying the older Paleozoic and Precambrian formations to the north and west. These sedimentary layers were uplifted following their deposition and now tilt seaward. This tilting increased the net speed of water flow from the mountains and resulted in the creation of numerous fluvial incisions in the sedimentary strata. Many of these incisions were filled by sediments deposited during later periods of marine transgression. Offshore, the coastal plain

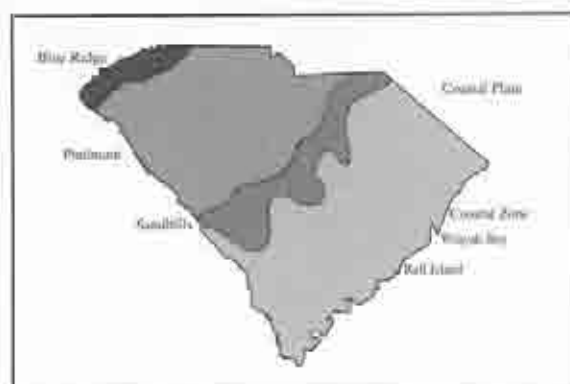


Figure 8.2. South Carolina's major physiographic zones.

extends to form the broad Atlantic Continental Shelf (Figure 8.4) (<http://tapestry.usge.gov/coastalplain.html>).

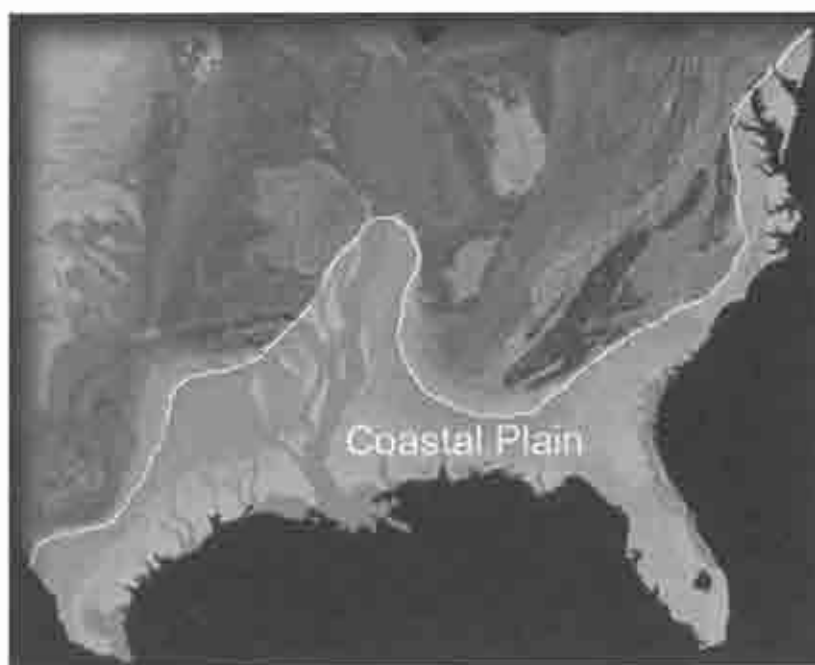
South Carolina's geological formations in the coastal zone range in age from Early Cenozoic to recent and overlie the older formations of Mesozoic basins (Table 8.1) (Shattuck 1906; Cooke 1936; Zeigler 1959; Colquhoun 1965, 1974; McCartan et al. 1984; Gohn 1983; Colquhoun et al. 1991; Weems and Lemon 1993). Inland of the coastal zone, in the region of South Carolina's sand hills, these deeper Mesozoic formations lie exposed or close to the surface, while in the Charleston area they lie approximately 1,150 m (3,700 ft.) beneath the present day surface. The Charleston area is located between the distinct geological features of the Cape Fear Arch to the northeast and the Southeast Georgia Embayment to the south and is characterized by marine, marine marginal and fluvial-estuarine sediments ranging in age from late Oligocene to Holocene (Weems and Lemon 1993:Sheet 1).

Coastal Geomorphology

Coastal geomorphology in the region of the *Hunley/Housatonic Site* is influenced by recent (Quaternary) geologic processes of sedimentation and marine transgression acting

Table 8.1. Age of geologic units encountered in the study area.

| Geologic Period | Geologic Epoch | Approximate Age | Dominant Features |
|-----------------|----------------|-----------------|---|
| Quaternary | Holocene | 10 ky to recent | Thin veneer of recent sediment overlying older units. |
| | Pleistocene | 1.8 my to 10 ky | Channel infill and dense tabular muds over shelf. |
| Tertiary | Pliocene | 5 my to 1.8 my | Phosphate and shell rich units which crop out at seafloor in places. Olive-gray sands with marine vertebrate and plant remains. |
| | Miocene | 23 my to 5 my | Erosion of Piedmont and Blue Ridge, fluvial deposition on coastal plain. |
| | Oligocene | 38 my to 23 my | Scouring of sedimentary strata by Gulf Stream. |

**Figure 8.3.** Coastal plain of the Southeastern US (courtesy of US Geological Survey (USGS)).

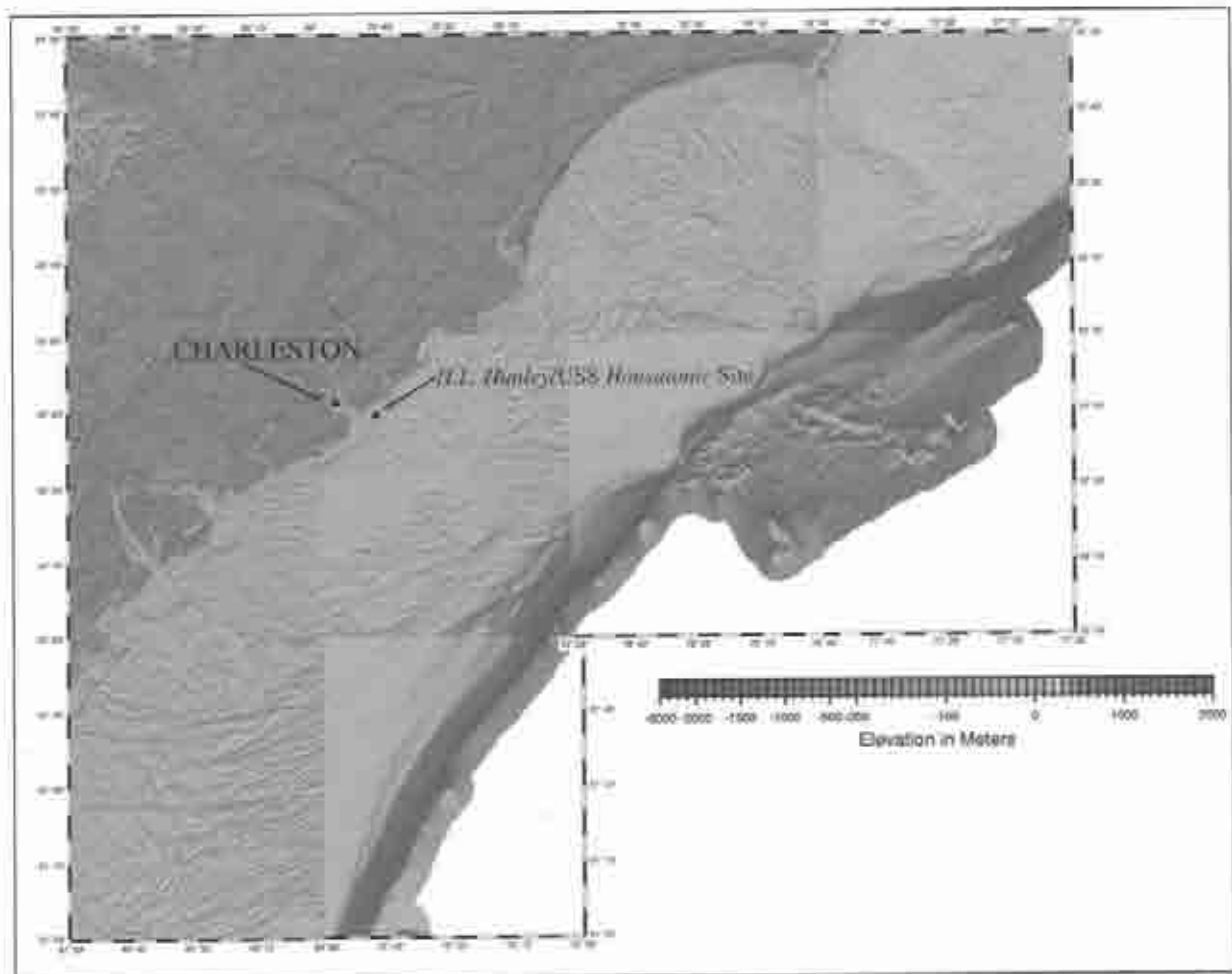


Figure 8.4. Continental Shelf of South Carolina (courtesy of National Oceanic Atmospheric Administration (NOAA)).

on the more permanent underlying structures of earlier Tertiary formations (Harris et al. 1997). Changes in sea level throughout the Pleistocene have left at least six, possibly seven highstands (remnants of earlier barrier islands, shelves and beaches) on the coastal plain inland of the modern coast (Cooke 1930, 1936; Colquhoun and Johnson 1967). Sea level changes over time have dictated local regions of sedimentary deposition and erosion, moving through and reworking earlier sedimentary units and filling incised channels with sedimentary layers. According to Weems and Lemon (1993:Sheet 1):

Virtually all the features which can be seen in this area [the Cainhoy, Charleston, Fort Moultrie and North Charleston quadrangles] resulted from the deposition of sediment along the Atlantic shoreline during interglacial intervals around 240 to 200 ka ago, 120 to 70 ka ago, during the middle Wisconsinian high-sea-level stand, and within the last 7 ka. Only minor modification by erosion along the larger river valleys has occurred during the intervening glacial intervals, so most deposits are well preserved and look nearly the same as when they formed. During glacial intervals, sea level was down 200 ft (60 m) or more below its present level (Blackwelder and others, 1979) and the presently sluggish streams in this area had gradients sufficiently steep to actively erode their streambeds. The results of this erosion mostly are buried now beneath the modern tidal estuaries, but a few streams are still actively downcutting into the Cainhoy barrier in the vicinity of the town of Cainhoy.

Tertiary features such as the Cooper, Ashley, Chandler Bridge, Edisto, Marks Head and Goose Creek formations are relatively dense, partially or wholly lithified, and act as a foundation for the weaker, less consolidated Quaternary layers that overlie them (Harris et al. 1997). These Tertiary formations are largely resistant to erosion and incision, and offshore they are occasionally exposed to form localized hardbottoms (Harris and Askins 1998:39; Poag 1984; Harris et al. 1997). In some places, however, Tertiary layers have been modified by fluvial incision, shoreface ravinement, inlet incision, and Gulf Stream erosion, processes that have secondary effects in the generation of Quaternary coastal geomorphology (Harris et al. 1996, Belknap and Kraft 1981, 1985; Popenoe 1986; Tye and Moslow 1994) (Figure 8.5). Tertiary subcropping units are often indicated in present-day coastlines by relatively stable barrier islands, while breaks in Tertiary strata are indicated by breaks in the barrier island chain such as Breach and Lighthouse Inlets (Harris et al. 1996:15).

The sea island complex in the Charleston area is characterized by small, wide, "drumstick-shaped" barrier islands that trend on a northeast-southwest axis (Figure 8.6). Their relative permanence is due in large part to the underlying Tertiary strata discussed above, while their size and shape is heavily influenced by prevailing currents and tides discussed below. While Tertiary strata are relatively stable, unconsolidated Quaternary layers of sand, sandy mud and shell are extensively reworked and redeposited by bioerosion, as well as currents generated by storms and tides. The upper Quaternary layers are extremely dynamic and can be redistributed over time-scales of weeks, months and years. Occasionally, episodic events such as hurricanes reshape entire sections of barrier islands in the space of a few hours. More

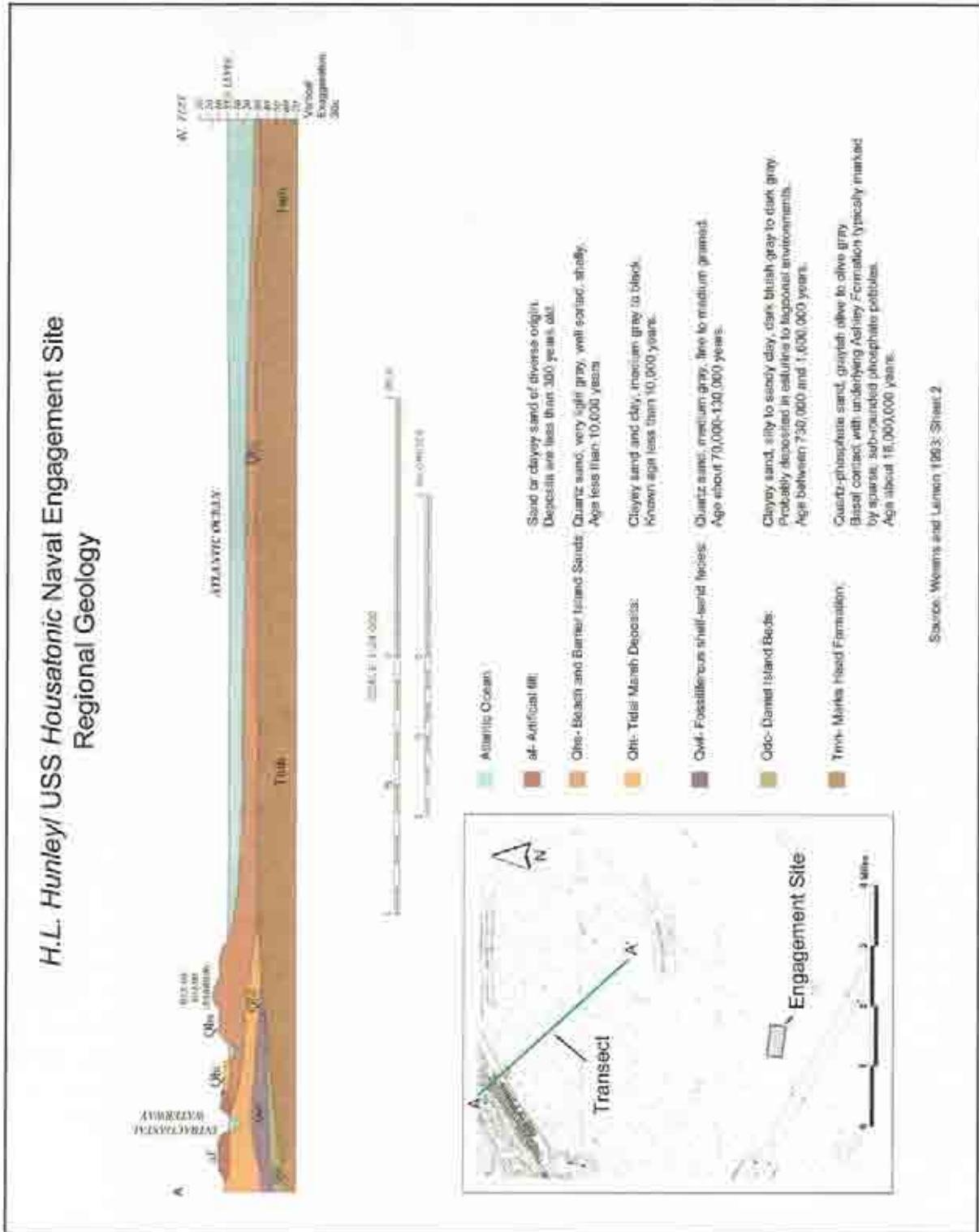


Figure 8.5. Regional geology of the *H.L. Hunley/ USS Housatonic* Naval Engagement Site (after Weems and Lemon 1983:Sheet 2).

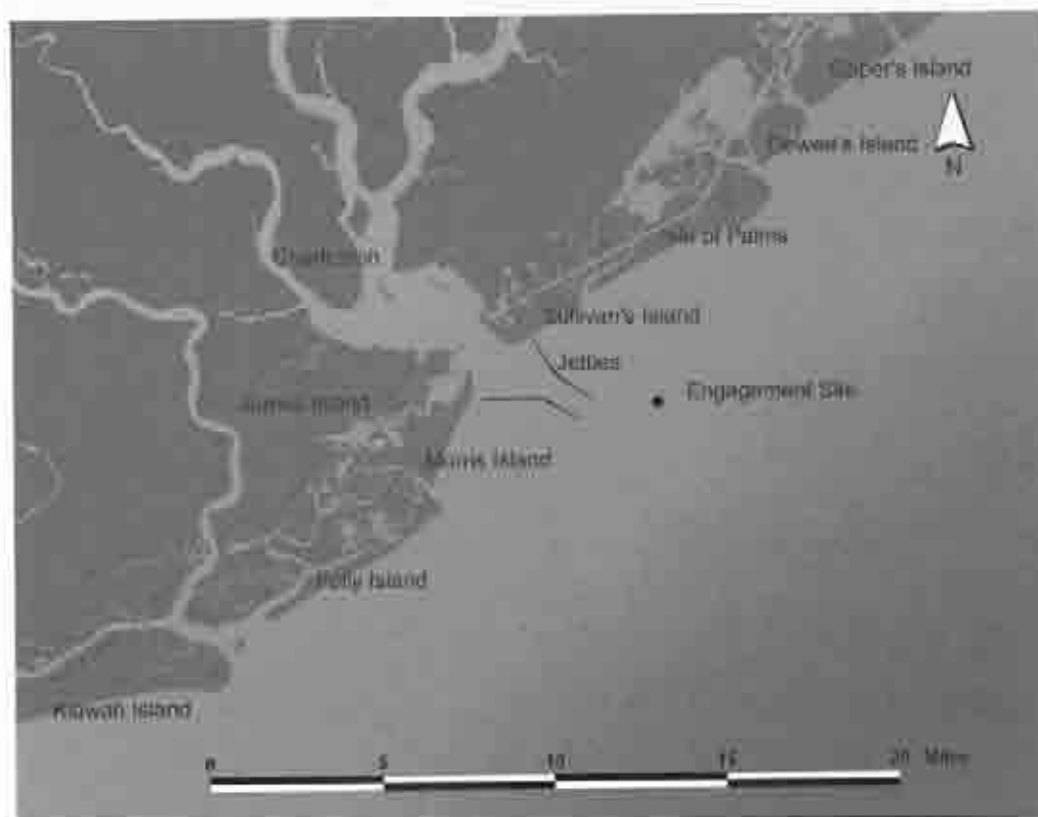


Figure 8.6. Coast of South Carolina adjacent to the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site.

gradual, but equally dramatic erosion rates reaching 15 m (50 ft.) per year have been documented at Morris Island, south of Charleston Harbor's entrance (Harris and Askins 1998:37; Hayes et al. 1984:13). Deeper Quaternary strata are typically cut with small, shallow channels that have been subsequently infilled. These stratigraphic incisions are remnants of tidal creeks of the sort now present in the back bay region between the barrier islands and the mainland or remnants of breaks in an earlier barrier island chain similar to Breach Inlet.

In South Carolina, the barrier islands are relatively short and backed by coastal wetlands and tidal stream systems that lie between them and the mainland. Although the barrier islands are separated by numerous small inlets, larger breaks in the barrier island chain into the

backing wetland system are typically 8 to 16 km (5 to 10 mi.) apart, whereas farther north, in North Carolina these inlets are 65 to 80 km (40 to 50 mi.) apart (Kana 1988:13–15). The closer spacing of breaks in the barrier island chain results in more, but smaller, tidal deltas with the subsequent concentration of small, relatively mobile sediment in offshore bars. Hayes (1979:58) has estimated that 75–80% of the sand in South Carolina's coastal zone is stored in ebb tidal deltas adjacent to coastal inlets.

Seismic Activity

The Charleston area sits close to the eastern end of the Blake fracture zone, a transverse fault line that runs perpendicular to the mid-Atlantic

ridge. South Carolina is seismically active and has experienced a number of earthquakes in the nineteenth and twentieth centuries. Seismic tremors were reported at Sullivan's Island in 1857 and 1952 (Weems and Lemon 1993:Sheet 1).

On August 31, 1886, one of the most powerful earthquakes ever to strike the eastern United States (7.7 on the Richter Scale) occurred with an epicenter approximately on the city of Charleston. Almost 90% of the buildings in the city were damaged and at least 60 people were killed by the quake (<http://www.ruf.rice.edu/~blakeney/quake.html>). The dense Paleozoic and Mesozoic strata underlying the looser Cretaceous to Holocene layers in the area (discussed above) may have channeled or magnified shock waves and contributed to the strength of the earthquake, which was felt as far away as Boston. Many small and medium-sized sand craters were formed by the quake, and large quantities of liquified sand were ejected from these craters in numerous areas. Poorly compacted geological layers experienced liquification with consequent settling of heavy objects such as homes and trees as the supporting matrix lost its bearing strength. Liquification features have been observed from Mount Pleasant to the eastern edge of the Charleston quadrangle (Weems and Lemon 1993:Sheet 1). Liquification of offshore sediments may also have occurred and this could have contributed to the settling of both *Hunley* and *Housatonic* through their supporting sedimentary matrices, though no direct evidence of this has been found.

SEA LEVEL CHANGE

Sea level change has been a determining factor in coastal geomorphology and sediment dynamics on the South Carolina coastal margin. From approximately 20,000 until 4,000 BP, glaciers in North America and Europe melted rapidly, raising sea levels approximately 106 m

(350 ft.) (Figure 8.7) (Kana 1988:11). Because South Carolina has a wide and shallow continental shelf, even relatively small changes in vertical sea level have translated into large horizontal displacement of coastlines, which explains the multiple highstands in the Charleston area. Data collected in Charleston indicate an average sea level change of approximately 3.4 mm/yr (0.13 in./yr) since 1922 (Figure 8.8). Using this rate, sea level has risen approximately 56 cm (22 in. or 1.84 ft.) since the sinking of both *Hunley* and *Housatonic* in 1864. This change must be factored into interpretations of sedimentation patterns and rates derived from charts made during the Civil War and modern charts.

CURRENTS, TIDES AND WAVES

Currents

The Gulf Stream, one of the world's largest ocean currents, moves northeastwards off the coast of South Carolina carrying warm water from the Gulf of Mexico into the North Atlantic (Figure 8.9). During the Oligocene, the current flowed west of its present position and created large sand waves that are now represented by phosphate deposits in the Tertiary strata of the study area (Popenoe et al. 1987; Harris et al. 1994). The Gulf Stream in its present location moderates climatic extremes for South Carolina but also intensifies hurricanes by providing thermal energy and moisture to ocean storm systems. Hurricane Hugo, which heavily damaged the South Carolina coast, increased from a category 2 to a category 4 storm after hitting the Gulf Stream on September 21, 1989 (Brennan 1991:4).

On a smaller scale, more localized, longshore currents are the result of prevailing wave patterns and tidal flow. Tertiary structures underlying the beach barrier island complex have forced the coastline in a northeast-

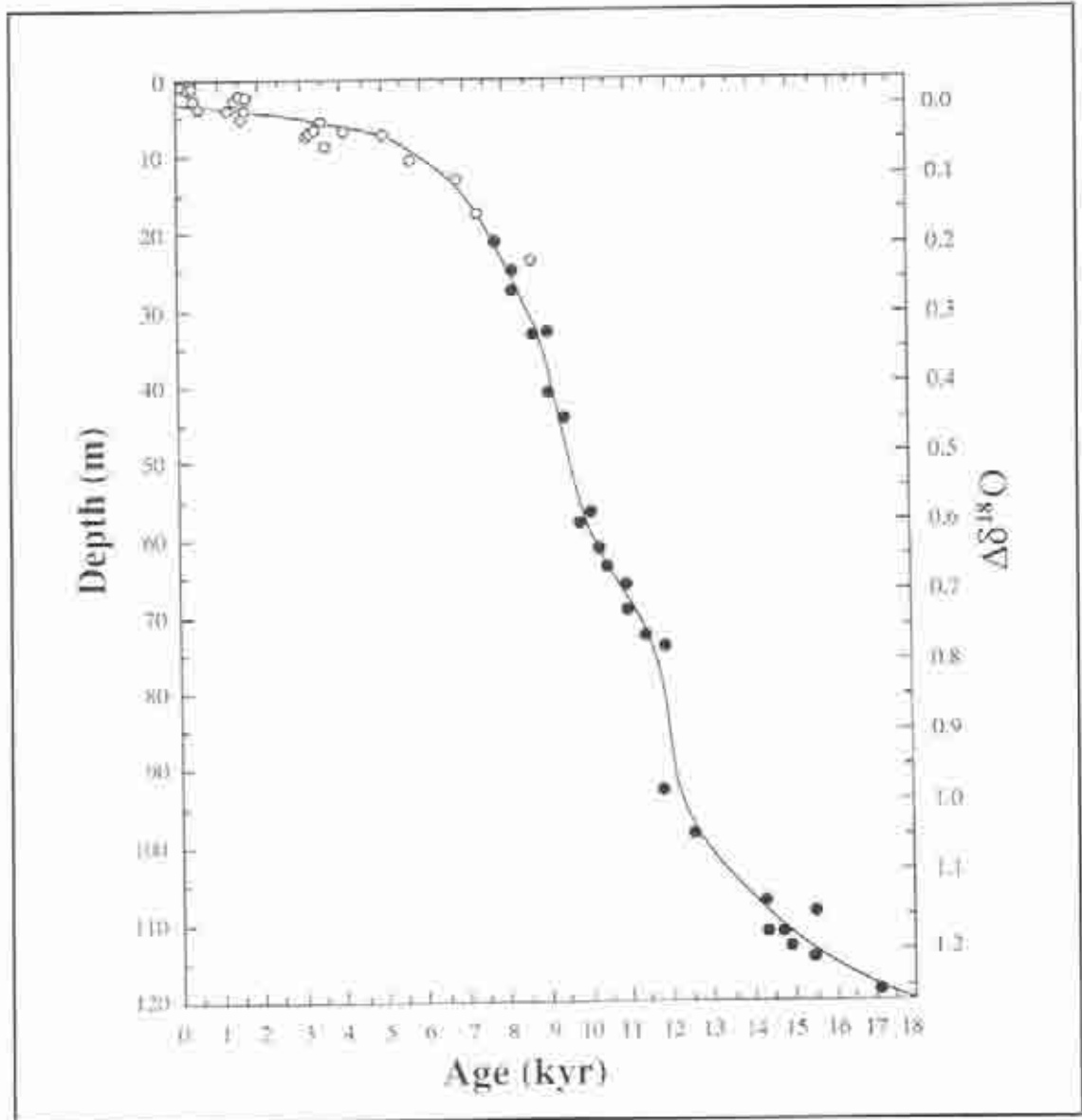


Figure 8.7. Quaternary sea level change (source R. G. Fairbanks 1989:66).

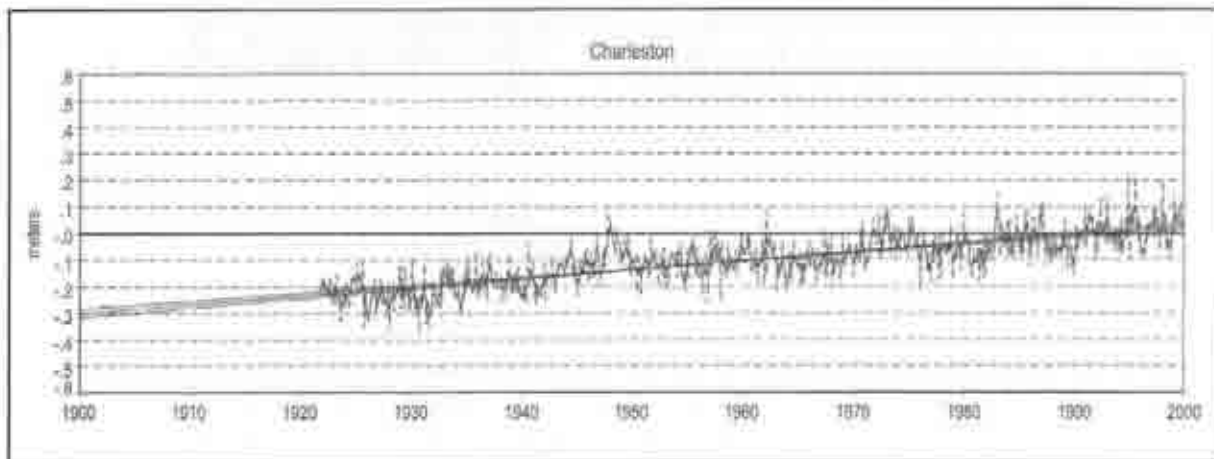


Figure 8.8. Charleston sea level trends 1921–2000 (compiled by NOAA).

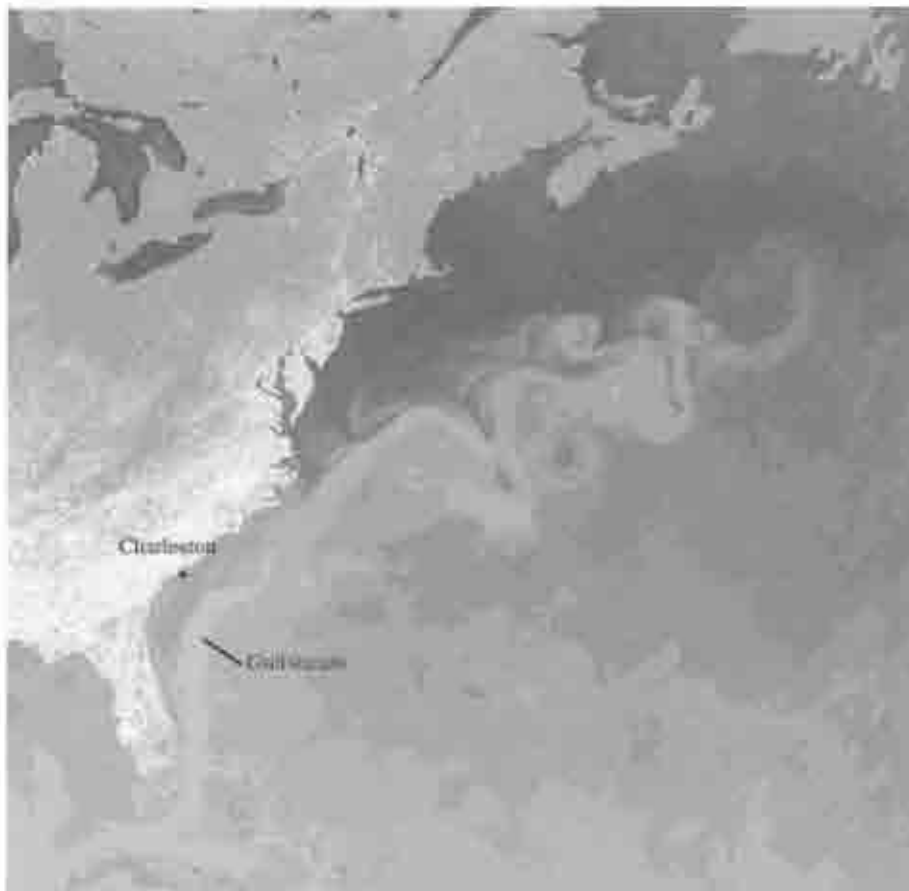


Figure 8.9. Gulf Stream (courtesy NOAA).

southwest trend in the area of Charleston and this, coupled with prevailing seas from the east and northeast, result in a net longshore transport from northeast to southwest. This prevailing current carries an annual sediment load of between 130,000 m³ and 290,000 m³/year southward along the coast and interacts with local tidal dynamics to shape sandbars off breaks in the sea island chain (Fitzgerald et al. 1979:6).

In addition to nearshore currents, the strongest currents in the area are tidally driven. The relatively wide, shallow continental shelf off South Carolina has the net effect of increasing tidal range while decreasing wave height and energy. Kana (1988:13) notes:

Because the continental shelf is wider off South Carolina and Georgia, the tidal range is at least twice as great as North Carolina's or Florida's: 6 to 7-foot tides each month, compared to 3-foot tides along the Gulf coast. On the other hand, wave energy in South Carolina is significantly lower. More tidal energy or lower wave energy allows more inlets to form and remain stable along our coast...

Of the two primary oceanographic factors, tides and currents, responsible for the size and shape of barrier islands in the Charleston area, tides are dominant. Tidal dominance of coastal sedimentation dynamics creates smaller, relatively stable islands intercut with numerous small inlets that trap a large amount of unconsolidated sediment in bars. During storm events or following alteration of coastal currents, sediments contained in these bars are often rapidly transported down current with a subsequent change in local bathymetry and geomorphology.

Tides

Tides in the Charleston area are semidiurnal and range from a mean of 1.6 m (5.2 ft.) to a maximum spring tide of 1.9 m (6.2 ft.) at the harbor entrance (Fitzgerald et al. 1979:4). Currents created by these tides are strongly asymmetrical with a measured maximum flood velocity of .93 km/h (0.5 kn.) and a maximum ebb velocity of 3.70 km/h (2.0 kn.) at the tip of the north jetty, 3.2 km (2 mi.) from the wreck of *Housatonic* (NOAA tidal data, Charleston Harbor). Other, smaller breaks in the barrier island chain such as Stono Inlet, show a similar disparity between slower incoming flood currents and faster outgoing ebb currents (5.0 km/h (2.7 kn.) flood vs. 8.7 km/h (4.7 kn.) ebb) (NOAA tidal data, Charleston Harbor).

Conceptually, the marshes and tidal flats separating barrier islands such as Isle of Palms and Sullivan's Island from the mainland can be seen as a funnel. The funnel is filled from the bottom by incoming tides, so as the tide rises, the volume of the back bay area to be filled increases. This increase in volume absorbs incoming water and has the net effect of slowing the speed of tidal rise as well as slowing the speed of incoming currents through breaks in the barrier island chain as tides reach their apex. With the outgoing tide the reverse is true—as the tide flows out of the back bay areas, the current is channeled through smaller channels and current speed increases. In addition to the geometry of the Charleston back bay region, outflows from the Cooper, Ashley and Wando Rivers contribute to a buildup of water in the harbor that must eventually flow into the sea through the narrow breaks in the barrier islands.

A final contributory factor to the disparity between incoming and outgoing tidal flow are the Charleston Jetties (discussed in detail below).

The inland ends of the jetties are lower than the offshore ends and this allows incoming tides to flow over the tops of the jetties along a relatively wide front. Outgoing tides, however, are channeled through the relatively narrow seaward end of the jetty and, because a huge volume of water must exit through a narrow outflow, net current speeds are much higher. This jet action, an intentional result of the jetty design, has the net effect of scouring the channel and preventing sediment buildup in the shipping channel leading into the harbor.

Waves

Hayes et al. (1984:3) have noted that waves are the dominant natural force affecting erosion and deposition along the coastal zone. Waves provide energy for the initial suspension of sediments that facilitates their transport by tidal and nearshore currents for redeposition elsewhere. As discussed above, waves from the

east-northeast striking the coast in the region of Charleston result in the net transport of sediment in a southwesterly direction.

Wave data for the study area have been collected from NOAA buoy #41004 located 57 km (36 mi.) east of the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site. Because the continental shelf is both wide and shallow off the South Carolina coast, waves are smaller, more closely spaced, and thus have less energy than waves off other areas of the Atlantic Coast. MacMahan (1997) found a 54+/-11% reduction from deep water wave heights to the inner shelf areas, due to the moderating effects of the shallow continental shelf.

Aggregated buoy data from May 1980 to December 1993 show an average significant wave height of 1.32 m (4.33 ft.) with a maximum significant wave height recorded as 6.6 m (21 ft.) in June and a minimum significant wave height of 0.2m (0.7 ft.) in July, August and December (Figure 8.10) (<http://>

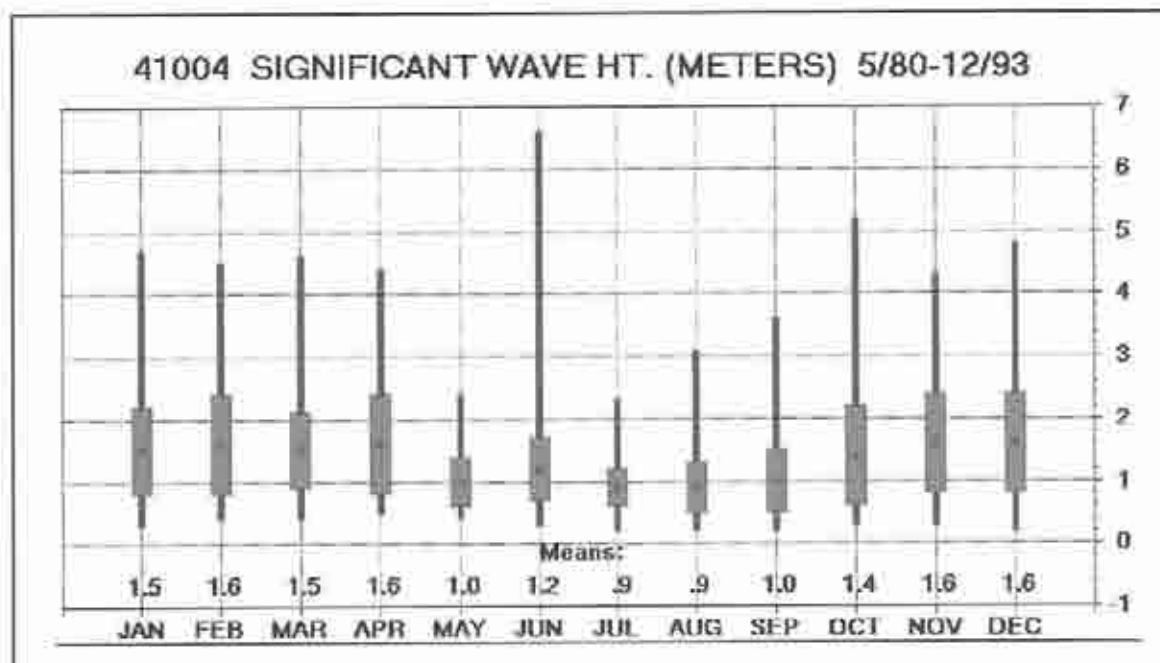


Figure 8.10. Significant wave height near the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site (courtesy NOAA).

www.ndbc.noaa.gov/images/climplot/41004_wh.gif). The annual average wave period is 5.0 seconds with an average maximum of 5.5 seconds in February and an average minimum of 4.6 seconds in January.

WEATHER AND CLIMATE

South Carolina is located in the northern mid-latitudes and has a climate characterized by hot, humid summers and mild, rainy winters. In addition to its relatively low latitude, the Atlantic Ocean, the Appalachian Mountain chain and low overall elevation are significant influences on statewide climate.

The Atlantic Ocean and the warm Gulf Stream act as a thermal reservoir and moderate climatic extremes during all seasons. During the summer, the sea provides cool sea breezes while in the winter it warms the coastal margin. In the summertime, daily disparities between land and sea temperatures draw moist air off the ocean and produce predictable cycles of afternoon thunderstorms with associated higher winds. In addition to localized effects of land and sea breezes, larger-scale processes also contribute to summer precipitation. Summer weather in South Carolina is dominated by the semipermanent structure of the Bermuda High. This region of warm, moist air centered roughly on Bermuda flows outwards in a clockwise direction. After passing over the South Carolina coastline, prevailing winds driven by the Bermuda High rise as they hit the Appalachian Mountain chain. As the air rises, it cools and precipitation results with concurrent local thunderstorms and precipitation maxima during the summer months of June, July and August (http://water.dnr.state.sc.us/climate/sco/sc_climate.html).

Another climatic influence is the Appalachian Mountains, which block cold air masses from moving into the state from the west and northwest and moderate the winters.

In addition, cool heavy air descending from the high mountains warms due to adiabatic heating, producing slightly warmer temperatures in the lee of the mountain chain. Finally, there is a distinct rain shadow on the eastern side of the Appalachians that ends roughly at the eastern edge of the Piedmont. During summer, the Appalachian chain often forms the western edge of the Bermuda High, and winds cycle over South Carolina from the south and southwest.

Along the coastal margin, daily cycles of heating and cooling alter these large scale winds creating localized patterns of south and southeast winds. During autumn, the mountains form the southern edge of a predominant high-pressure cell known as the "Wedge," which is centered over New England and that creates predominantly northeast winds. In the winter, the Appalachians steer low pressure systems northeastwards creating southwest then northeast winds (http://water.dnr.state.sc.us/climate/sco/sc_climate.html).

Temperature

The annual temperature in South Carolina varies from the mid-50s in the mountains to low 60s Fahrenheit along the coast. During winter, average temperatures range from the 30s in the mountains to the low 50s on the coastal margin. During summer, mountain temperatures are in the upper 60s in the mountains and mid-70s along the coast. Snow and hail are rare on the coastal plain. (http://water.dnr.state.sc.us/climate/sco/sc_climate.html). Temperature affects vegetation growth, which in turn, affects water run-off, river flow and sediment transport. Warm temperatures combined with a relatively humid climate and low relief along the coastal plain have created a series of dense marshes and forests that absorb much of South Carolina's rainfall before it is incorporated into the river system.

Precipitation

Aggregated statewide, South Carolina has two precipitation maxima, one in March and the other in July. On the coastal margin around Charleston, however, precipitation peaks in August due to the effects of summer thunderstorms as well as tropical storms and hurricanes. No month averages less than 5 cm (2 in.) of rainfall anywhere in the state. Overall, precipitation in the area is generally highest during the months of June, July and August, and annual rainfall for the coastal margin ranges from 114–127 cm (45–50 in.) per year (Figure 8.11) (http://water.dnr.state.sc.us/climate/sco/sc_climate.html). Increased precipitation increases stream and river flow and therefore outgoing tidal speed, sediment transport and channel incision. Higher speeds for outgoing tides may resuspend deposited sediment and move it farther offshore. Increased sediment transport deposits material offshore and may contribute to site burial, while channel incision may change areas of sediment accumulation.

Extreme Climatic Events

Drought

Drought occurs in South Carolina on an average of once every 30 years, and severe droughts have occurred statewide in 1818, 1845, 1890, 1925, 1933, 1954, 1977, 1983, 1986, 1988, 1990 and 1993 (<http://water.dnr.state.sc.us/climate/sco/severe.html>). Droughts denude the landscape of vegetation and increase erosion, which in turn increases river sediment loads and coastal sedimentation.

Floods

Paradoxically, floods often follow droughts due to a lack of vegetation that contributes to

extra runoff. The 1990 drought was followed by devastating floods on October 10–13 and again on October 22 when the remnants of Hurricane Klaus and Tropical Storm Marco moved through South Carolina. In 1908, all major rivers in the state rose from 2.75 to 6.7m (9–22 ft.) above flood levels, and in 1903 between 60–80 people died in a flash flood on a tributary of the Broad River in north central South Carolina (<http://water.dnr.state.sc.us/climate/sco/severe.html>). These floods washed extensive sediment into the river and stream systems that was subsequently deposited offshore in ebb tidal deltas.

Hurricanes

Since 1871, at least 45 tropical storms and hurricanes have affected the South Carolina coast (Harris and Askins 1998:41; Department of the Army 1990). Of those 45 storms, 30 had eyes that entered the state and 9 produced severe to catastrophic damage. (<http://water.dnr.state.sc.us/climate/sco/hurricane.html>). The hurricane of August 1893 made landfall near Savannah, Georgia, with winds of 120 mph. in Beaufort and Charleston causing extensive flooding along the South Carolina coast. More than 2,000 people drowned (<http://water.dnr.state.sc.us/climate/sco/severe.html>). Hurricane Hazel came on the heels of a month-long drought in 1954 and made landfall just south of the North Carolina border on October 15. Winds in excess of 100 mph. were reported in the Myrtle Beach area and storm surge was 5.5 m (18 ft.) at the North Carolina border (http://www.nhc.noaa.gov/HAW/basics/historic_storms.htm#top). Hurricane Hugo tracked directly over the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site on September 22, 1989, and had a catastrophic impact on the Charleston area.

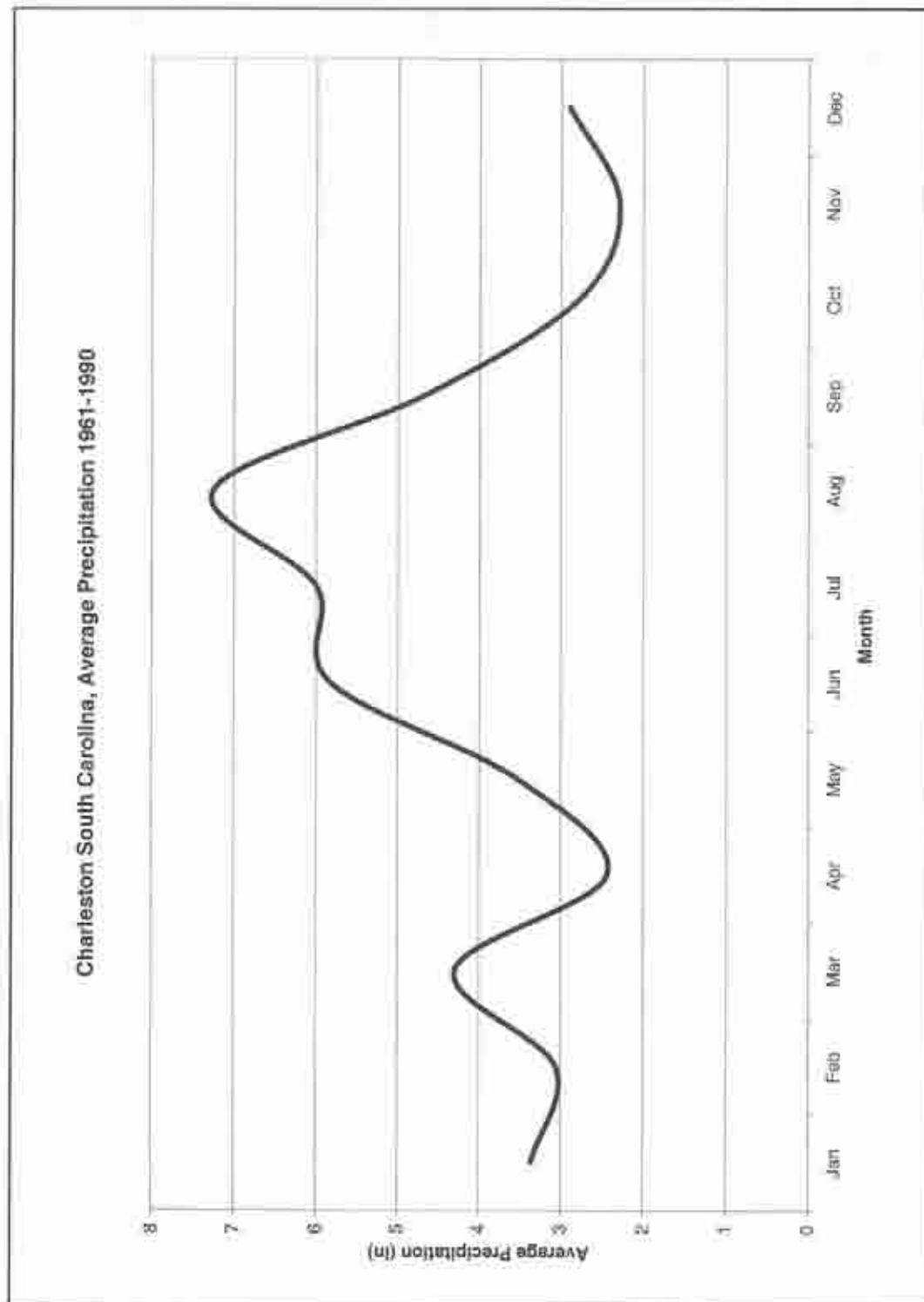


Figure 8.11. Average precipitation in Charleston 1961–1990 (courtesy South Carolina Department of Natural Resources).

SITE-LEVEL PROCESSES

GEOLOGY

Of all environmental variables pertinent to an understanding of the Engagement Site, coastal sediment characteristics are the most important. A microscale characterization of the geological environment surrounding the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site draws heavily upon data from remote sensing and the nine vibracores recovered by U.S. Geological Survey (USGS) and Coastal Carolina University geologists around the site (Chapter 4), as well as analyses of the vibracores conducted by geologists from both USGS and Soil Consultants, Inc. (Appendices D and F). Based upon an analysis of sediments surrounding *Hunley*, principal sediment types are fine to medium sands, clays and silts. Course sands and fine gravels are also present but in small quantities and only in distinct stratigraphic layers. In addition to sands, silts and clays, lenses of shell and shell hash are spread discontinuously throughout the site (Chapter 4). Very light, soupy "pluff mud" encountered in pockets onsite during excavations was not present in the recovered vibracores.

Sediment Age

Sediments north and inshore of the engagement site, as indicated by Weems and Lemon (1993:Sheets 1 and 2), are Holocene beach and barrier island sands with a relatively high shell content overlying the deeper Miocene strata of quartz phosphate sands from the Marks Head Formation (Figure 8.5). Vibracore data from the Engagement Site are somewhat at odds with the Weems and Lemon interpretations and show well-sorted Holocene layers of silty sand with shell overlying thick olive gray to dark gray Pleistocene clay layers interbedded with sand and shell layers. The Pleistocene layers are

probably from the Daniel Island Beds, a stratum found in USGS boreholes from Sullivan's Island approximately 6.9 km (4.3 mi.) west of the Engagement Site (Weems and Lemon 1993:Sheet 1). The vibracores did not produce strata with characteristics that would identify them as part of the Miocene Marks Head Formation, although sub-bottom profiler data may show the distinctive phosphate layer discussed by Weems and Lemon (1993:Sheet 1, Table 8.2).

Lead 210 (^{210}Pb) isotopic dating of upper level sediments in vibracores HOUS 3 and HUSB-1B provides age data for sedimentary layers in the Engagement Site within approximately the last 100 years (Appendix F). Sediment ages for the layers differ between the two cores, with the *Hunley* core showing older dates near the surface and the *Housatonic* core having older dates in deeper strata. These data indicate an overall higher sedimentation rate near *Housatonic* and a lower sedimentation rate near *Hunley* (0.74 ± 0.25 cm/yr. for *Hunley* and 0.89 ± 0.3 cm/yr. for *Housatonic*). In both cases, the amount of ^{210}Pb in sediments below a few decimeters was beneath the detection threshold and was, therefore, older than approximately 100 years (Appendix F).

The generally exponential decay of ^{210}Pb as a function of depth below modern bottom in both vibracores indicates that accretion of sediments over both *Hunley* and *Housatonic* was not punctuated by large episodes of erosion (Appendix F). This helps explain the superior preservation of *Hunley* as documented in 1996 (Murphy, Lenihan and Amer (1998:119) as well as the numerous small and delicate artifacts recovered during fieldwork on *Housatonic* (Chapter 4). Sedimentary deposition, though not interrupted by periods of erosion, was probably episodic with relatively large amounts of sediment deposited on site in short periods of time due to events such as storms and, as discussed below, changes to coastal

Table 8.2. Age of geologic units proximate to or present in vibracores.

| Geologic Period | Geologic Epoch | Formation Name | Approximate Age | Dominant Features/Description (After Weems and Lemon 1993:Sheet 2). |
|-----------------|----------------|--------------------------------|-----------------|--|
| Quaternary | Holocene | Beach and Barrier Island Sands | 10 ky to recent | Surface deposits; light gray, fine grained, well sorted, quartz sands; shelly. |
| | Pleistocene | Daniel Island Beds | 1600 to 730 ky | Clayey sand, silty to sandy clay, dark bluish gray to dark gray, clay-rich beds sticky. Probably deposited in estuarine to lagoonal environments. |
| Tertiary | Miocene | Marks Head Formation | 18 my | Quartz-phosphate sand, grayish olive or olive gray; fine grained. Basal contact with the Ashley Formation typically marked by sparse, sub-rounded phosphate pebbles. |

sedimentation dynamics caused by human actions.

Sediment Characteristics

Sediments in the region of the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site are primarily fine and medium sands, clay layers and silt. Three of the recovered vibracores (HUSB 1A, HUPS 2A and HUPB 1A) were sub-sampled at different depths and run through a series of sieves in accordance with American Society for Testing and Materials (ASTM) methods for particle size analysis of soils (ASTM D 422-63) (Appendix D). Taken as an aggregate, the core subsamples are predominantly fine sand (49.7%), clay (29.4%) and silt (13.6%) with smaller percentages of medium sand, coarse sand and fine gravel (Figure 8.12). There is no

clear correlation between sediment depth and size of constituent particles, a fact consistent with the extensive reworking and infill episodes characteristic of sediments on the coastal margin (Figure 8.13).

In addition to sediment size analysis, sub-samples of the vibracores were analyzed in accordance to ASTM methods for unconfined compressive strength (ASTM D 2166-00), a procedure that provides an approximate value of the strength of cohesive soil under pressure. This series of tests was done to assist in planning for the recovery of *H.L. Hunley*, but also provided important information relevant to site formation processes within the Engagement Site (Chapter 3). Sediment cohesive strength varies from 9.56 kg/cm² to 75.58 kg/cm² (136 to 1075 psi.) with a slight trend towards more cohesive strength in deeper layers (Table 8.3) (Appendix

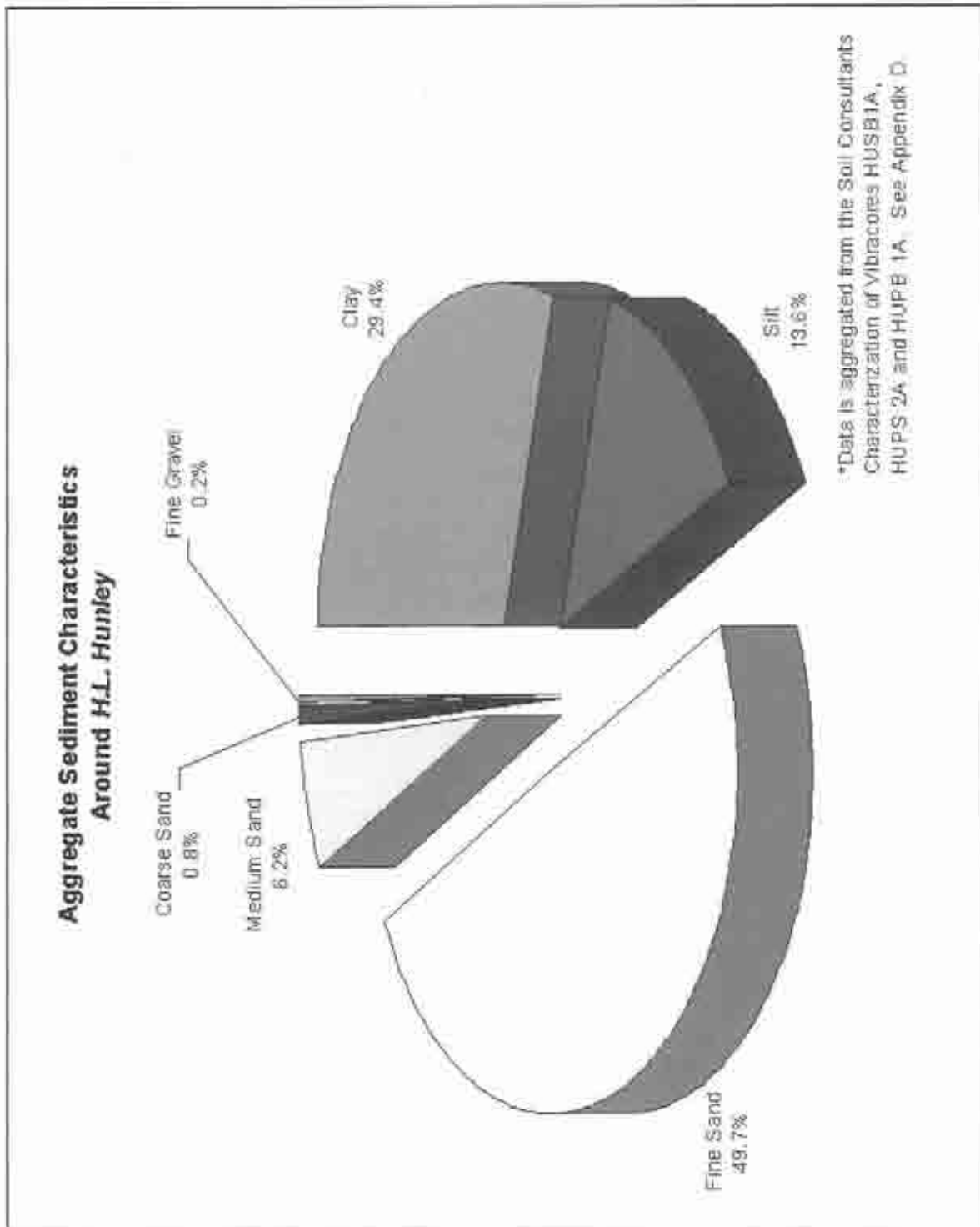


Figure 8.12. Aggregate sediment characteristics around H.L. Hunley.

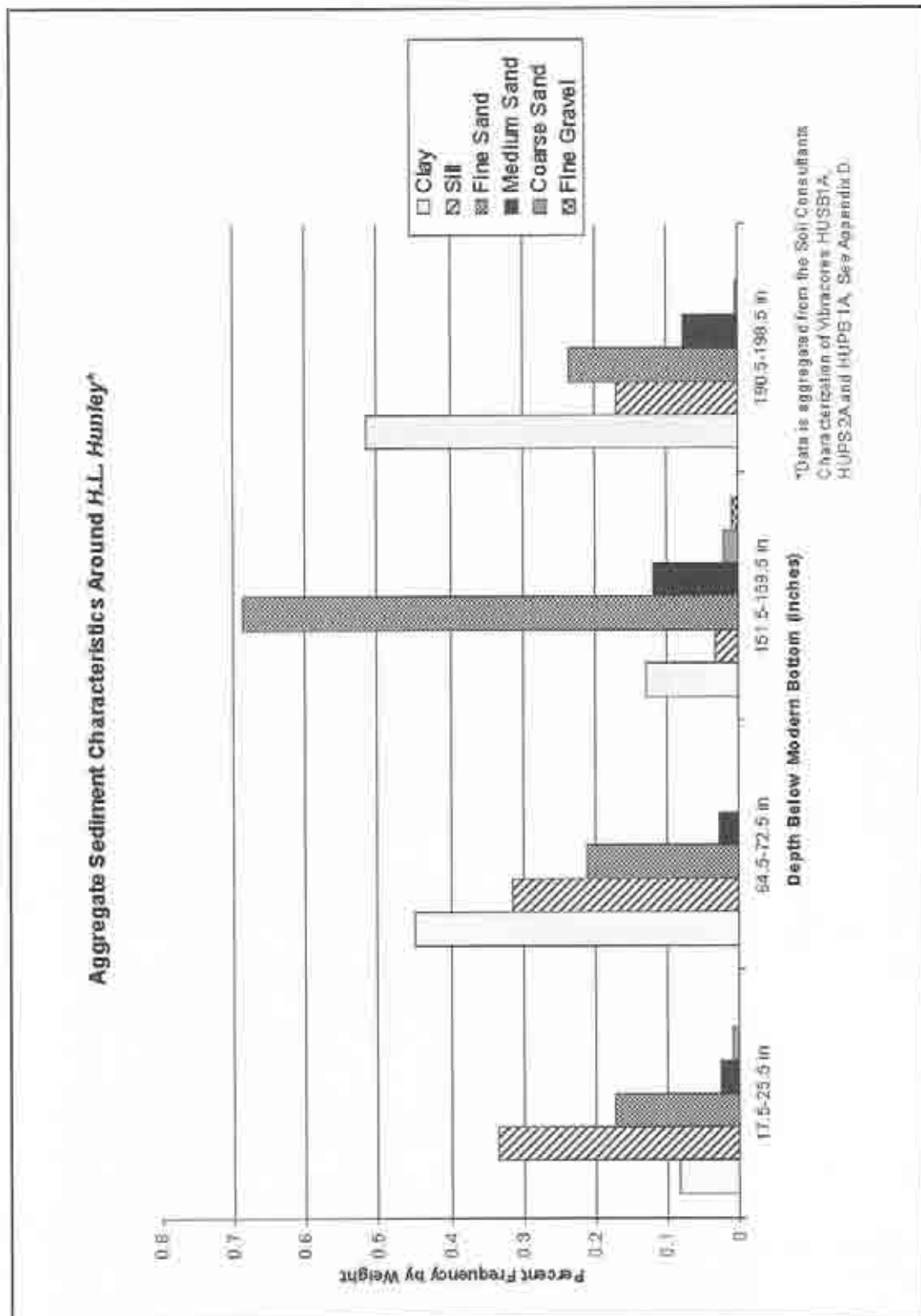


Figure 8.13. Aggregate sediment characteristics around *H.L. Hunley* by depth.

D). More important to site formation processes, (primarily scouring and settling of *Hunley*, *Housatonic* and the Third Anomaly, discussed in Chapter 9) is the relative change in cohesive strength from one layer to another. Averaged together, sediment cohesion increases by a factor of more than 2½ between .55 m and 1.77 m (1.8 ft. and 5.8 ft.) below the modern bottom, and increases 2¼ times between 1.77 m and 3.96 m (5.8 ft. and 13 ft.) below the modern bottom (Table 8.3). Of the three vibracores analyzed, only one subsample (from HUSB 1A) was recovered at a mean depth of 3.96 m (13 ft.). It is interesting to note that the underlying layer has less cohesive strength than the layer above it. This accords well with the observed stratigraphy of dense, compact layers of clay and silt alternating with looser layers of sand and shell, as well as the interpretation that these lower strata are from the Pleistocene Daniel Island Beds.

Site Stratigraphy

Vibracores

Altogether nine vibracores were taken from the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site, and of those nine, eight were split open and analyzed for stratigraphy, sediment characteristics, and sediment dates

(Chapter 4). In general, the stratigraphy of the vibracores is characterized by sand and shell strata interspersed with clay (Figure 8.14). The primary units in the cores are a mixture of Holocene sands, overlying an olive-gray to dark gray stratum of Pleistocene clay. The Pleistocene stratum is present in both *Hunley* and *Housatonic* vibracores. In the *Hunley* vibracores, the Pleistocene clay overlies Pleistocene sand and shell strata with another Pleistocene clay stratum in the basal layer of the vibracores.

The Holocene layers overlying the top Pleistocene clay stratum are loose sands and shell, with the *Housatonic* vibracores displaying more stratigraphic variability than the *Hunley* vibracores. The variability in the upper strata of the *Housatonic* vibracores may be indicative of multiple depositional episodes and extensive reworking of sedimentary layers. This probably also reflects the overall higher sedimentation rate (as indicated by the ^{210}Pb data) over the wreck of *Housatonic* compared to the rate over *Hunley*. Of particular interest is the stratum of blue-gray clay at about -121 cm (4 ft.) in *Housatonic* cores HOUS-1, HOUS-2 and HOUS-3 which is geologically similar to the gray Pleistocene clay stratum in the lower portions of the cores. This layer of blue-gray clay, overlying a Holocene sand and shell stratum may be displaced Pleistocene clay from dredging operations that

Table 8.3. Sediment cohesive strength.

| | | HUSB1A | HUPS 2A | HUPB 1A | |
|--|-------------|-------------------|-------------------|-------------------|---|
| Mean Depth Below Modern Bottom (ft.) | Sample Age | Cohesion (psi) | Cohesion (psi) | Cohesion (psi) | Percent Change from Overlying Layer (Average) |
| 1.8 | Holocene | 179 | 136 | 295 | 0 |
| 5.8 | Pleistocene | 476 | 437 | 330 | 266% |
| 13.0 | Pleistocene | 1075 | No Data | No Data | 226% |
| 16.3 | Pleistocene | 501 | 554 | 365 | -53% |



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H.L. Hunley/USS Housatonic Naval Engagement Site

Sedimentary Stratigraphy

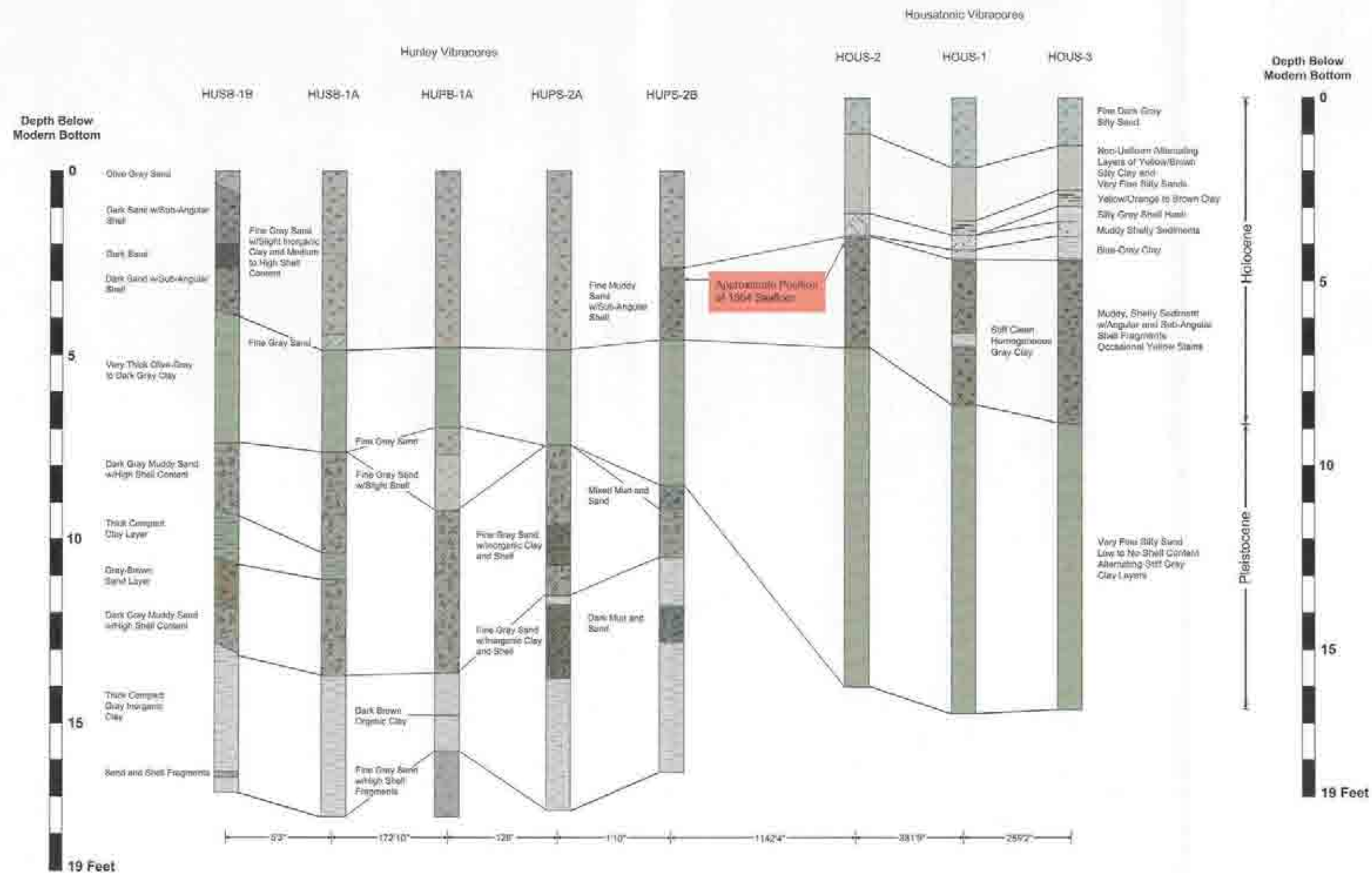


Figure 8.14. H.L. Hunley/USS Housatonic Naval Engagement Site stratigraphy.

accompanied the construction of the Charleston Jetties from 1877 to 1895 (discussed below). In addition, the layer of non-uniform, alternating layers of yellow-brown silty clay and very fine silty sands in the *Housatonic* cores ranging in depth from -30 to 106 cm (1 to 3 ½ ft.) may be either directly deposited freshwater sediments caused by the diversion of the Santee River in 1941 (discussed below) or additional dredge spoil from harbor maintenance operations that accompanied the Santee River diversion.

Beneath the top strata of Pleistocene clay in all five *Hunley* vibracores is a complex series of sand and shell strata that are probably the remains of earlier back barrier/estuarine deposits that were incised by tidal creeks or the remains of offshore tidal channels. Of particular interest are vibracores HUPS-2A and HUPS-2B that, though taken very close together, display quite different stratigraphic sequences in their lower strata. This may be the result of creek or tidal channel incision of earlier strata that were subsequently infilled. The complex interleaving of the strata in the lower margins of the *Hunley* cores, particularly in vibracore HUPS-2A, is probably indicative of cyclic processes of incision and deposition of sediments in a back barrier or estuarine environment. Because these layers lie below the temporal resolution of the ^{210}Pb data, this interpretation is based largely on the coastal dynamics of the region. *Hunley*, unlike *Housatonic*, may lie in the now infilled channel of an earlier break in the barrier island chain.

Geostar Chirp Sub-bottom Profiler Data

An acoustic sub-bottom examination of sediments in the area of the Engagement Site was an important part of the remote sensing done at the outset of the project (Chapter 4). Both a wide-band Geostar chirp instrument employing multiple sound frequencies and single-frequency

Applied Acoustics boomer instrument were used. The multiple frequencies of the chirp instrument ensured that reflectors in shallower strata were well documented, while the lower, single frequency of the Applied Acoustics instrument gave a better characterization of deeper, underlying strata. Higher frequencies produce better resolution but at the cost of penetration, while lower frequencies penetrate deeper into sedimentary strata but at the cost of resolution.

Correlation of stratigraphic sequences from the vibracores with chirp and boomer sub-bottom data, though desirable as a research objective, was not possible. This was due to the inherent differences in the resolution of both sub-bottom instruments compared to that possible using visual examination of the vibracore strata. Visual examination of the vibracores disclosed many subtle strata that were not shown in either chirp or sub-bottom data. Also, penetration depths for the Geostar chirp instrument of about 12.5 m (41 ft.) and the Applied Acoustics sub-bottom of about 49.5m (162 ft.) makes meaningful comparison with vibracores with a penetration depth of approximately 5.2 m (17 ft.) difficult.

Geostar chirp data shows numerous paleochannels throughout the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site that have been filled by marine transgression. These data are congruent with interpretations of local geologic history and correlate well with the interpreted presence of Daniel Island Bed strata in the eight recovered vibracores (Weems and Lemon 1993; Harris and Askins 1998:39; Poag 1984; Harris et al. 1997). Typically, the banks of the paleochannels have been cut down by wave action during transgression and, therefore, full cross-sections of the channels are not usually represented in the chirp data.

An examination of a representative sub-bottom image shows a prominent paleochannel

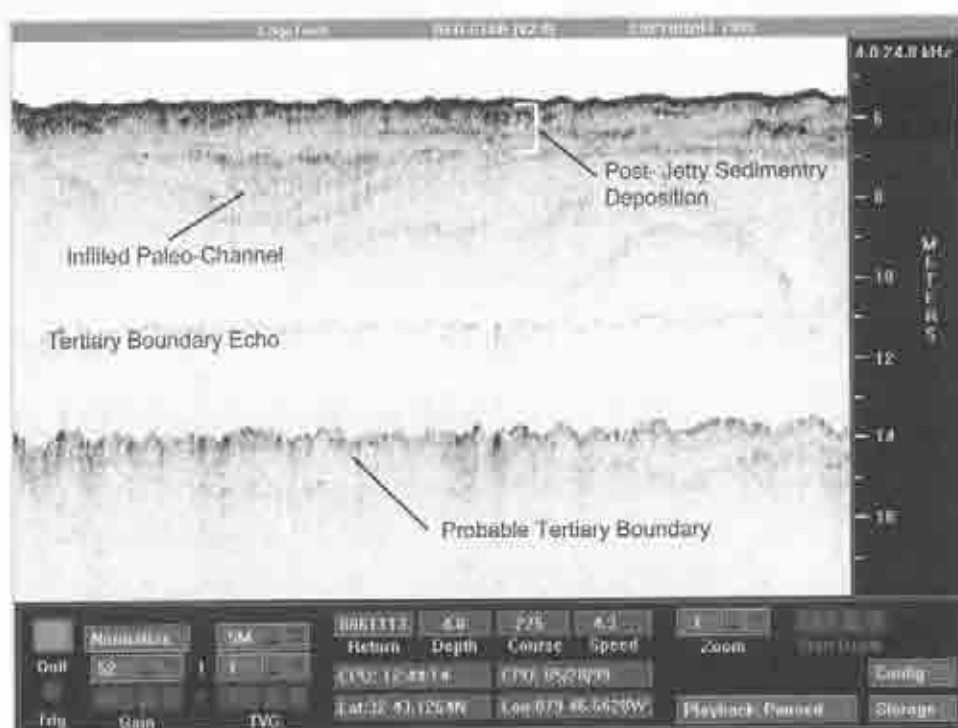


Figure 8.15. Geo-star CHIRP sub-bottom image of sediments around the *H.L. Hunley/USC Housatonic* Naval Engagement Site.

with multiple bank positions indicative of either meandering or narrowing of the channel over time (Figure 8.15). On the lower margins of most of the chirp images is a hard reflective stratum that produces an echo in the overlying layer. This hard reflective stratum correlates well with a thin phosphate stratum from other deep cores taken within the study area and probably marks the base of the Tertiary Marks Head Formation or, less likely, the base of the Tertiary Ashley Formation of the Cooper Group (Weems and Lemon 1993:Sheet 1).

Of particular interest to an understanding of site formation processes for *Housatonic*, *Hunley* and other elements of the Engagement Site is a distinct reflector in chirp images at approximately 1–1.3 m (3–4 ft.) below modern bottom. Based on sedimentation rates derived from ^{210}Pb data (above and Appendix F), as well as comparative historical bathymetry (below), this strata marks

the position of the seafloor prior to the construction of the Charleston Jetties (discussed below). Strata between this layer and the modern bottom is the result of post-jetty sedimentary deposition and partially explains both observed burial of *Housatonic*, *Hunley* and other elements of the site as well as the superior preservation of many fragile artifacts recovered during fieldwork (Chapters 4 and 5).

Applied Acoustics Sub-bottom Data

Applied Acoustics sub-bottom data correlate well with chirp data and show numerous filled paleochannel incisions in strata underlying the *Hunley/Housatonic* Site (Figure 8.16). The deeper depth of the sub-bottom data, as compared to chirp or vibracore data shows channels from an earlier, probably Tertiary, series of marine transgressions in the area.

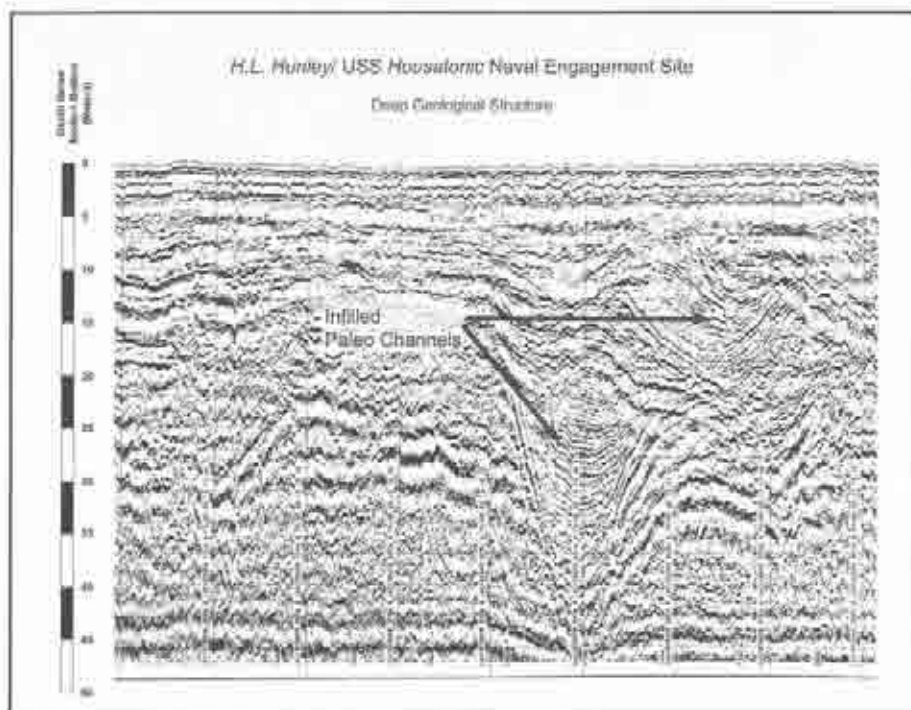


Figure 8.16. *H.L. Hunley/USS Housatonic* Naval Engagement Site deep geological structure.

SEA LEVEL CHANGE AND COMPARATIVE BATHYMETRY

Comparison of bathymetric data from 1890 and 1990 indicates both the 7- and 8-m (23 and 26 ft.) isobath have moved offshore near or over the wrecks of *Hunley* and *Housatonic* (Figure 8.17). This is due to changes in the coastal sedimentation regime caused by the construction of the Charleston Jetties. Coupled with this is the sea level rise of estimated 56 cm (22 in.) since 1864—data that further increase the net magnitude of bathymetric changes over the site (Lyles et al. 1987; <http://www.biol.sc.edu/~morris/sealev.html>).

Reliable bathymetric data exist for the Engagement Site as a result of survey work done during the *Hunley* assessment in 1996. Corrected for tidal changes, water depths are

7.76 m (25.45 ft.) below mean low water (MLW) over *Housatonic* and 8.37 m (27.46 ft.) over *Hunley*.

Water depth over the *H.L. Hunley/USS Housatonic* Naval Engagement Site in 1870 was approximately 8.07 m (26.5 ft.) MLW (Coast Survey, Charleston Harbor and Approaches, 5th Edition) and is currently between 8.37 and 7.76 m MLW (25.45 and 27.46 ft.). Sea level rise of approximately 56 cm (22 in.) since 1864 must also be factored into an analysis of historical bathymetry. In 1858, the depth at the site was recorded at between 5 and 5.25 fathoms (9.14–9.44 m or 30–31 ft.) which, given sea level rise, would be approximately 9.75–10.05 m (32–33 ft.) for 1999 values, indicating an approximate sediment increase of 1.22–1.52 m (4–5 ft.) between 1858 and 1999 (Scott Harris, personal communication 2001).

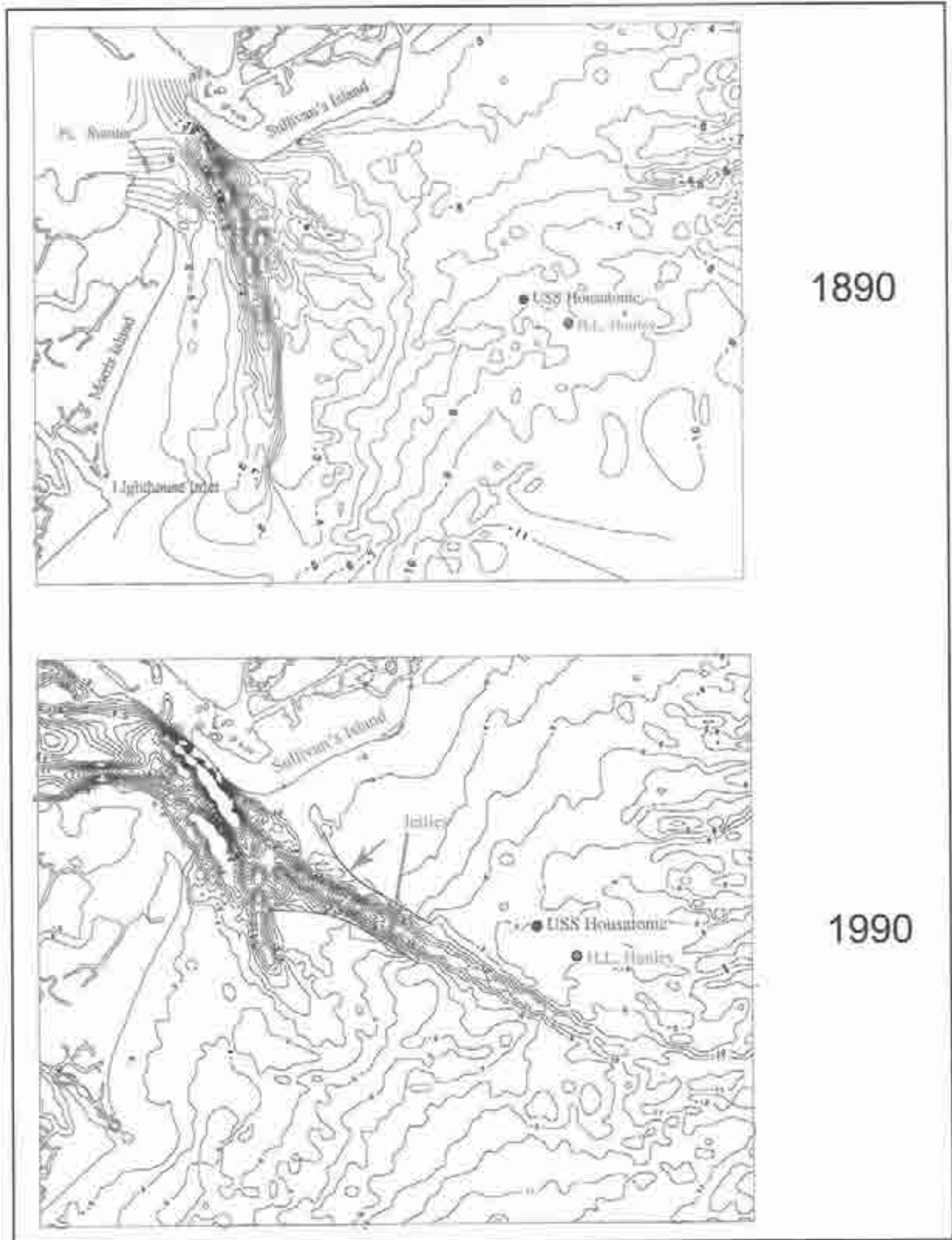


Figure 8.17. Comparative bathymetry 1890–1990 (courtesy Mark Hansen, USGS).

| Location | High Tide Range | Low Tide Range |
|--------------------|--------------------------------------|--|
| Isle of Palms Pier | 2.07 to 1.13 m (6.8 to 3.7 ft.) MLLW | 0.58 to -0.27 m (1.9 to -0.9 ft.) MLLW |
| Breach Inlet | 2.07 to 1.13 m (6.8 to 3.7 ft.) MLLW | 0.61 to -0.9 m (2.0 to -0.9 ft.) MLLW |

TIDES AND CURRENTS

Tides

Tidal information is available for points close to the *H.L. Hunley/USS Housatonic* Naval Engagement Site and is important because tidal flow is a significant source of energy directly affecting site components. In addition, water depth over the site determines effects that waves have on underlying sediments.

The nearest tidal stations to the site are the Isle of Palms Pier 7.27 km (4.51 mi.) NNE and Breach Inlet 7.30 km (4.54 mi.) NE of the site (NOAA tidal data).

Currents

Current information is also available for points close to the *H.L. Hunley/USS Housatonic* Naval Engagement Site and is important because current speed determines the size and amount of sediment transported onto or off the site. Surface current data is available for the North Jetty, 2.37 km (1.47 mi.) SW and Fort Sumter Range Buoy Number Eight 1.7 km (1.06 mi.) W of the site.

Though surface currents do not translate directly into a characterization of bottom

currents, current data combined with a Hjulstrom diagram (Figure 8.18) offers an insight into both sediment movement around elements of the *Hunley/Housatonic* site under the influence of tidal currents as well as possible processes of scouring and settling. A Hjulstrom diagram graphically illustrates the current velocity required to suspend, move and deposit sediments of different grain sizes. On the *x* axis is sediment grain size, while on the *y* axis is current speed. Both axes are logarithmic scales.

In general the Hjulstrom diagram shows that there is no simple correlation between current speed and its ability to pick up and transport sediments. Clay and fine sediments have a high cohesive value and are relatively resistant to erosion by current while large grained particles are also relatively resistant to erosion due to their mass. Clay, once suspended in a current is very slow to be deposited, while pebbles and cobbles are quickly deposited following relatively minor decreases in current speed.

In the upper strata of the vibracores, 43–65 cm (17–25.5 in.) below modern bottom, analyzed by Soil Consultants, Inc. (Appendix D) (Figure 8.19), silt and fine sands account for 50.5% of the total sample by weight. These fine sands and silts fall more fully in the erosional range of the ebb tidal current speeds for the two

| Location | Flood Current Range | Ebb Current Range |
|--------------------------|----------------------------------|-----------------------------------|
| North Jetty | 10 to 26 cm/sec (0.2 to 0.5 kn.) | 36 to 102 cm/sec (0.7 to 2.0 kn.) |
| Fort Sumter Range Buoy 8 | 21 to 51 cm/sec (0.4 to 1.0 kn.) | 31 to 81 cm/sec (0.6 to 1.7 kn.) |

locations nearest the Engagement Site than in the flood tidal current range.

In general, currents in the area of the Engagement Site display a decrease in velocity with increasing depth. Thus, as the water deepens off shore, sand and silt suspended in the water column by wave or current action precipitate and are deposited. The net effect is that sediments picked up from shallower areas or already suspended in the outgoing tidal stream move offshore and settle. Because the incoming tidal current is both slower and does not come in contact with the bottom with a great deal of velocity, sediments are not moved back onshore by a similar process.

Aggregate sedimentation rates, as indicated by the ^{210}Pb data (above and Appendix F) show a marked difference between the vibracore recovered close to *Housatonic* and the vibracore

recovered close to *Hunley*. *Housatonic*, closer inshore, has a 27% higher sedimentation rate than *Hunley*. This disparity in sedimentation rate over a distance of approximately 304 m (1,000 ft.) may indicate that a boundary condition for sediment suspension and transport is passed somewhere between these two principal components of the Engagement Site.

An application of Bernoulli's law indicates that, all factors being equal, speed will increase on the down current side due to a drop in pressure (Scott Harris, Personal Communication 2001). Because current speed increases, its ability to transport sediment also increases. As sediments are picked up and moved away, they create a hole that slowly envelops an obstruction which eventually sinks into the bottom. This helps explain the scour and settling of *Housatonic* observed by Lieutenant Churchill's

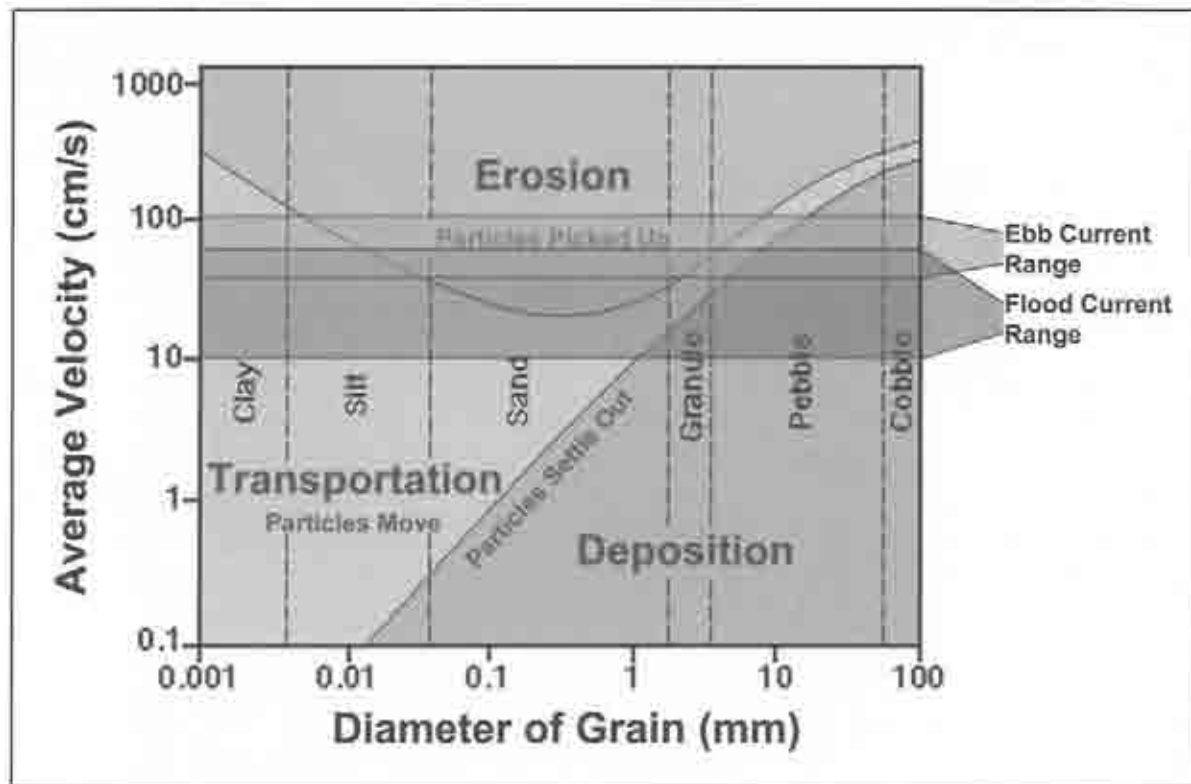


Figure 8.18. Hjulstrom diagram with ebb and flood current ranges (after Holmes 2001).

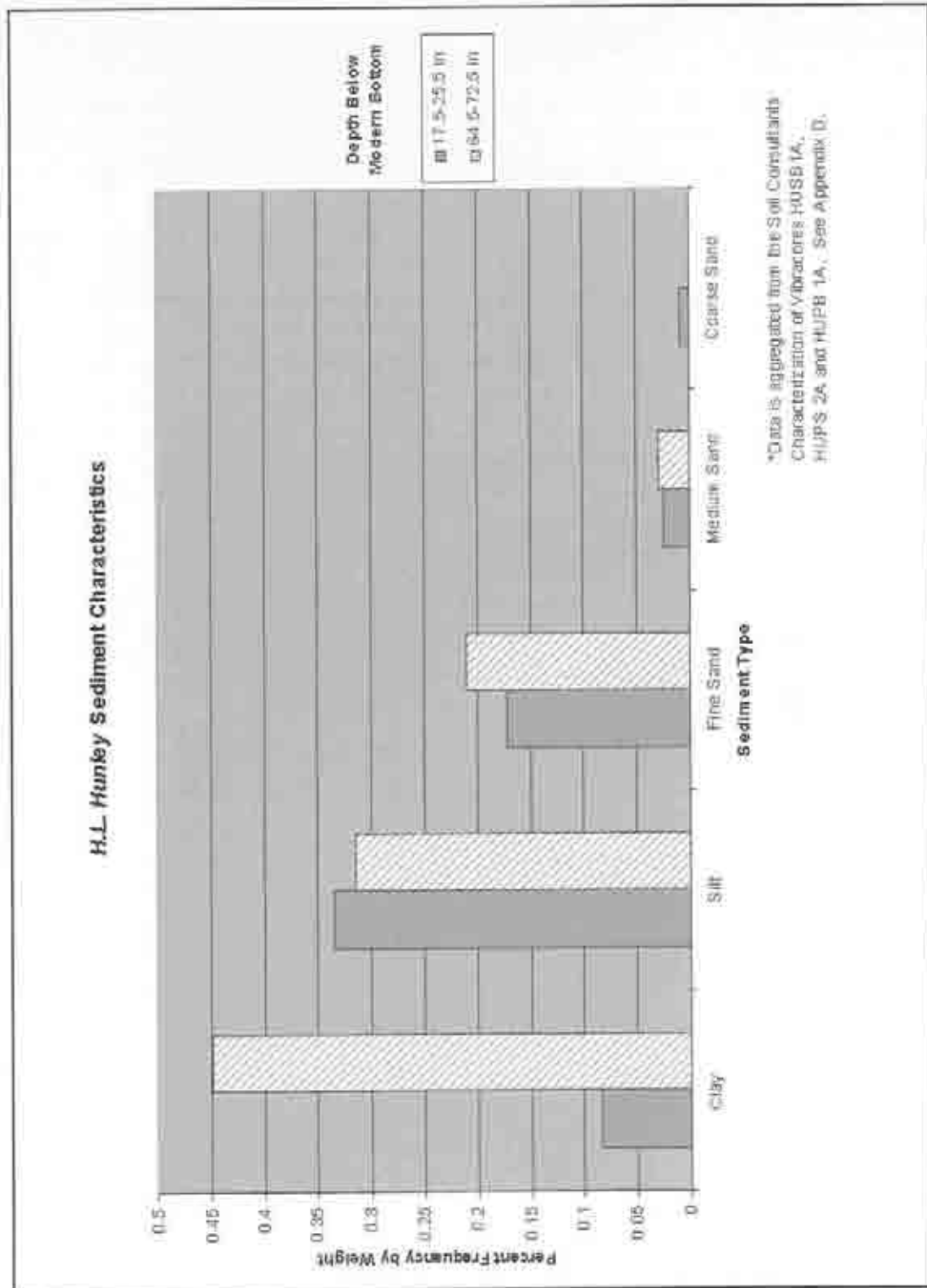


Figure 8.19. Aggregate sediment characteristics around *H.L. Hunley*.

divers in November 1864, 10 months after sinking (Chapter 2).

A characterization of sediments at depths between 163 to 184 cm (64.5 and 72.5 in.) (Figure 8.19), which is in the Pleistocene clay layer, shows that clay comprises 44.8% of the sample by weight. Looking at the Hjulstrom diagram (Figure 8.18) and bearing in mind that the diagram's axes are logarithmic, the erosion of clay particles requires a current speed of approximately 300 cm/sec or roughly three times the measured maximum surface ebb current velocity. Even the increase in current velocity caused by Bernoulli's Law acting on an obstruction would probably not be sufficient to cause extensive erosion in this stratum. Scouring and settling of *Housatonic* and other components of the Engagement Site through this Pleistocene clay layer, therefore, would be a much slower process.

WEATHER

Wind Speeds and Directions

The National Oceanic and Atmospheric Administration (NOAA) operates an automated weather reporting station on Folly Island 11 km (7 mi.) southwest of the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site. Data from 1984 to 1998 indicate that southwest winds are most common in the area (21.36%) followed by northeast winds (15.86%) (Figure 8.20). Winds of Beaufort force 3 (7–10 kn. or 12–18 km/h) are most common (30.79%) followed by winds of Beaufort force 4 (11–16 kn. or 20–29 km/h; 25.33%) (Figure 8.21). Statistically, October is the stormiest month for the area, and 9.98% of all data for that month indicate winds of Beaufort force 5 (31–38 km/h) or higher. Annually, winds of Beaufort 5 or higher comprise 6.62% of all data.

Hurricane Hugo

Since 1871, at least 45 tropical storms and hurricanes have affected the South Carolina coast (Harris and Askins 1998:41; Department of the Army 1990). Of these 45 storms and hurricanes, none had more effect on the Charleston area than Hurricane Hugo.

Hurricane Hugo started as a cluster of thunderstorms off the coast of West Africa on September 10, 1989. After growing from a tropical depression to a tropical storm and then a hurricane, it devastated parts of the eastern Caribbean and then veered northwards. On September 21, Hugo hit the Gulf Stream and grew in intensity to a category 4 hurricane with maximum sustained winds of 220 km/h (138 mph.) (Brennan 1991:4). Minutes before midnight on September 22, at about the same time as high tide, Hugo crossed almost directly over the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site and slammed into the coast at Sullivan's Island (Figure 8.22).

Pushed by extreme winds, a storm tide of up to 6 m (20 ft.) submerged parts of the South Carolina coast. In downtown Charleston, a storm surge of 3.5 m (11.5 ft.) was measured by the Customs House (Brennan 1991:10). Both Sullivan's Island and Isle of Palms were completely inundated by storm surge and most buildings on them were destroyed or heavily damaged. Coastal dunes on both islands were severely eroded and their sand transported inland as overwash or offshore (Stauble et al. 1991:161). In addition to storm surge, 10–15 cm (4–6 in.) of rain fell on South Carolina's coastal margin as a result of the storm and caused flooding along the Cooper, Ashley and Wando Rivers. Van Dolah and Anderson (1991:92) measured lowered oxygen levels in Charleston Harbor 11 days after the storm and speculated that this was due to the decay of large quantities of organic materials

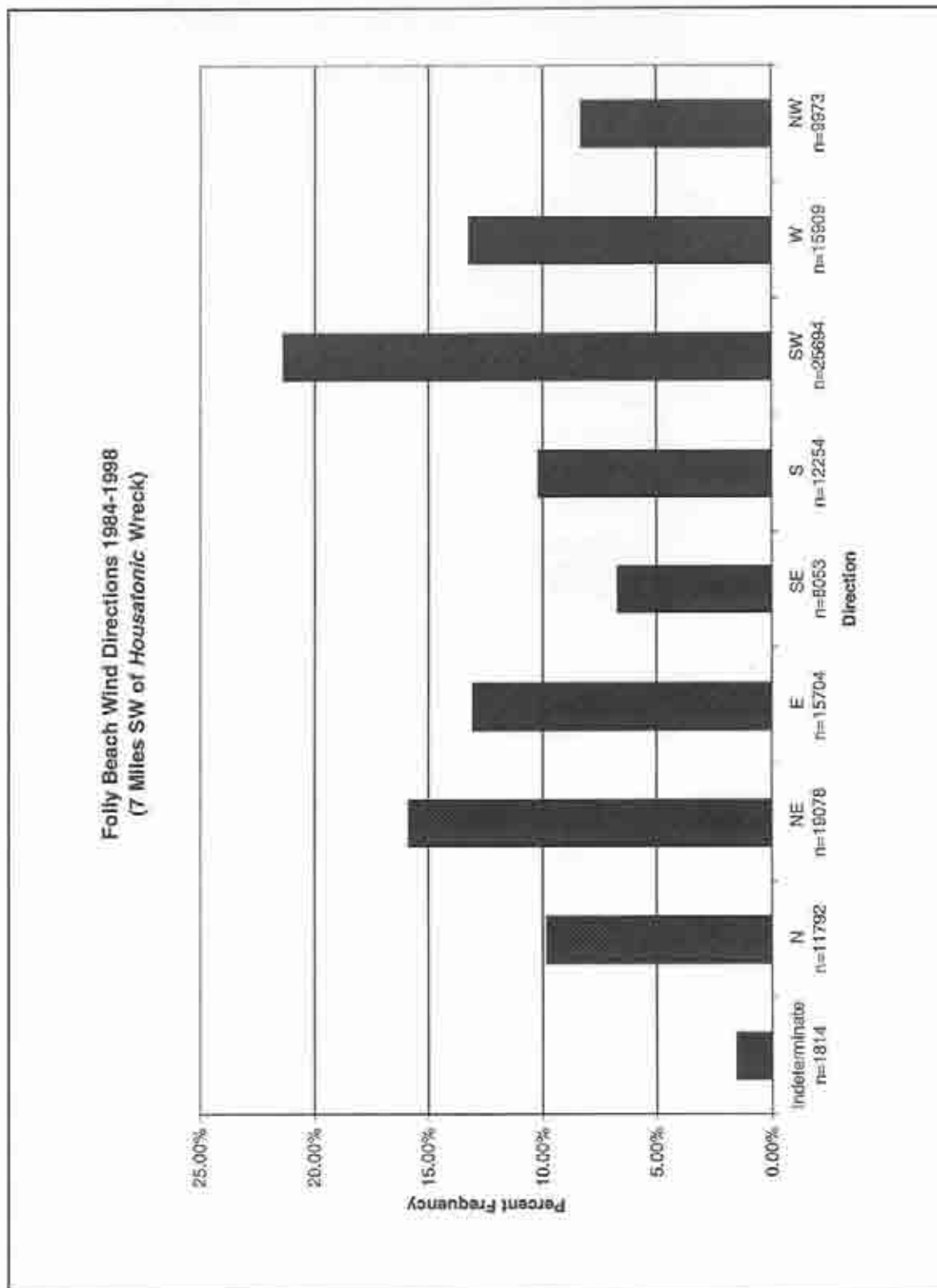


Figure 8.20. Folly Beach wind directions 1984–1998 (courtesy NOAA).

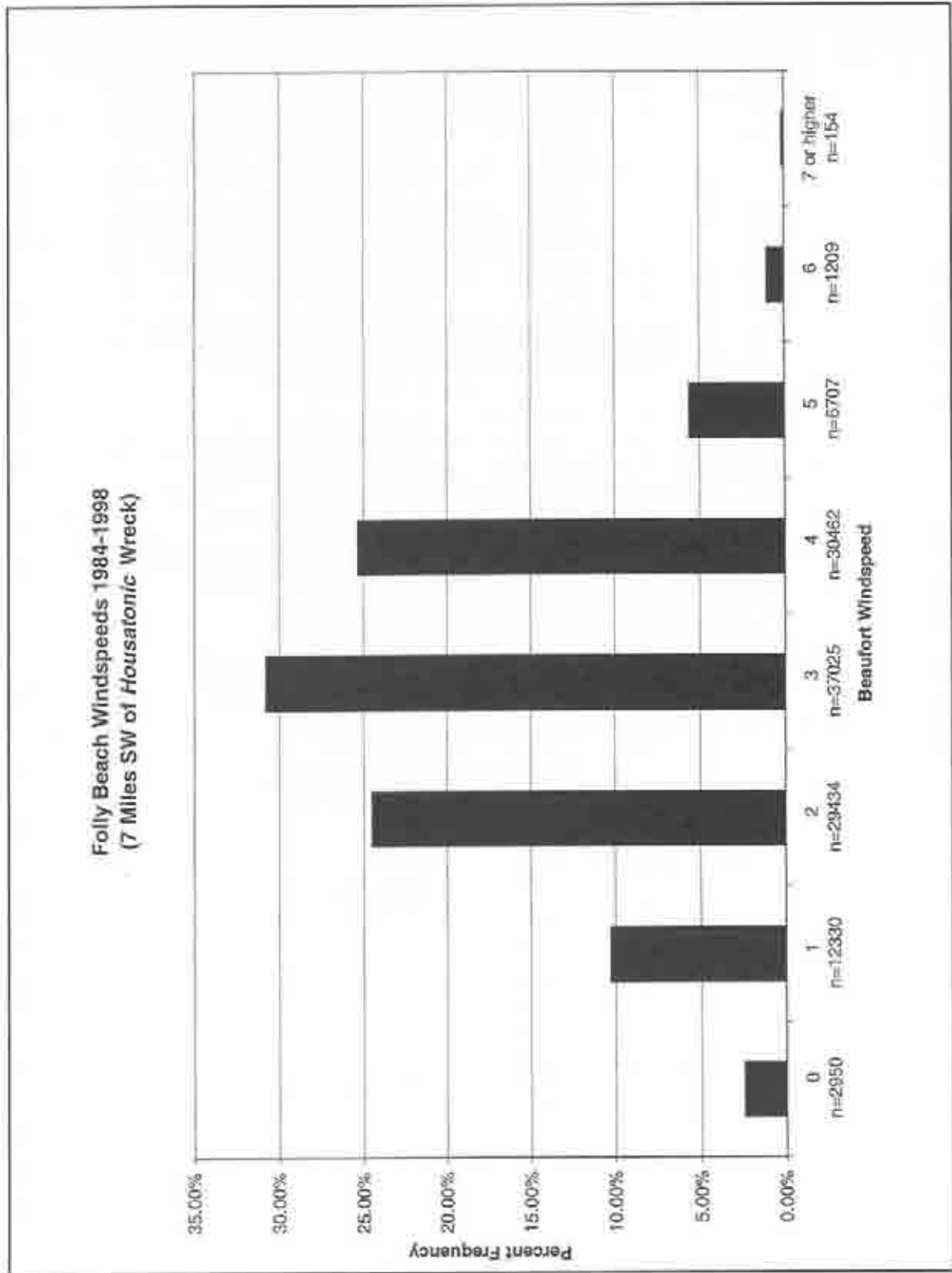


Figure 8.21. Folly Beach windspeeds 1984-1998 (courtesy NOAA).

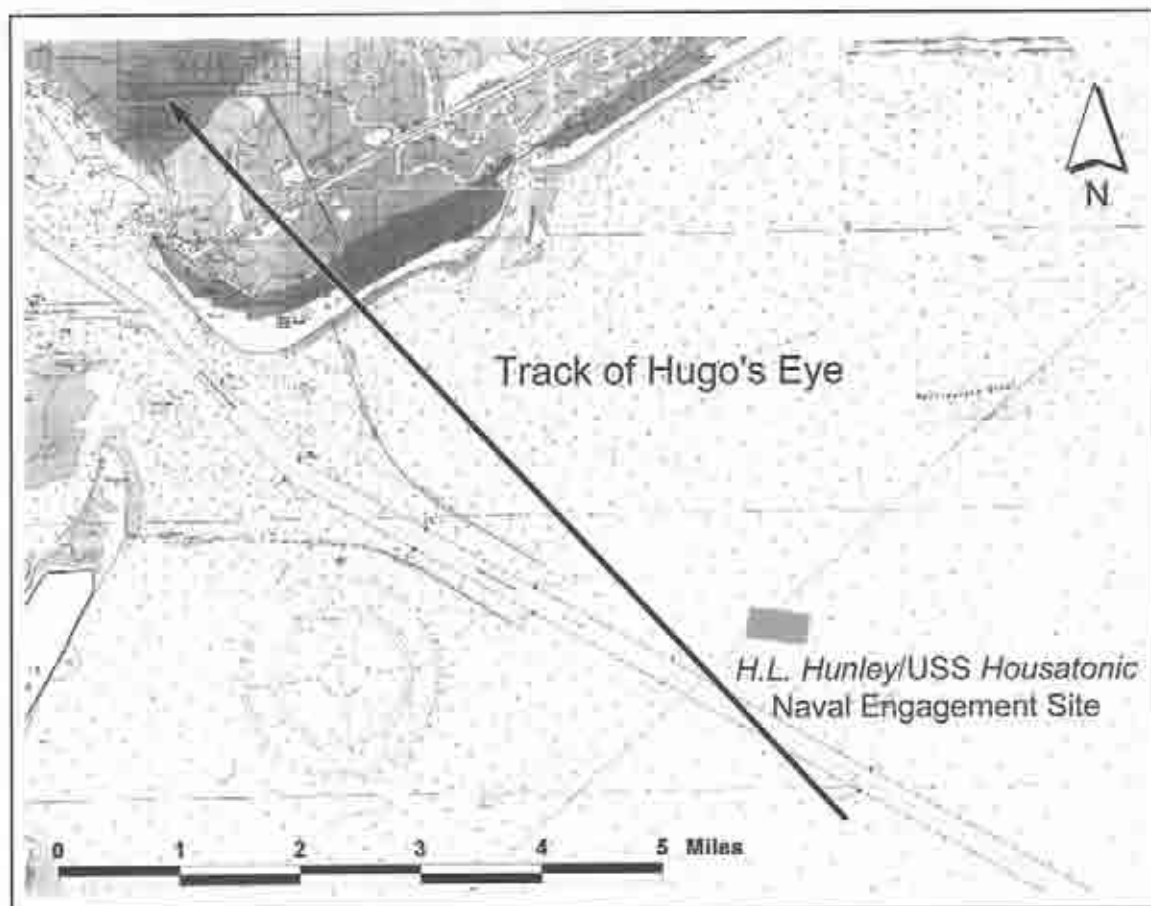


Figure 8.22. Track of Hurricane Hugo over the *H.L. Hunley/USS Housatonic* Naval Engagement Site.

washed into the harbor by flood water and storm surge.

As the storm passed, floodwater and storm surge held in Charleston Harbor as a hydraulic head flowed back seawards through new and existing breaks in the barrier island chain in a massive intensification of already existing ebb tidal flow processes. This rebound surge carried with it large quantities of sediment and debris from the barrier islands, nearshore, and the ebb tidal deltas where most of the sand in South Carolina's coastal zone is stored. At Breach Inlet, a beach monitoring station examined after the storm showed that large volumes of sand had been moved offshore (Katuna 1991:267).

As Gayes (1991:101) observed:

Extensive but smaller debris was found in water depths of greater than 4 meters [13 ft.]. Floating debris, trees and wooden construction materials, were identified up to 8 kilometers [5 mi.] offshore several weeks after the storm. While specific transport pathways and directions for nearshore sands are definable only in a general sense the identification of large dense particles, from identifiable source structures, clearly demonstrates the intensity of offshore directed transport or combined

flow on the lower beach/upper shoreface during the storm ... Extensive on-offshore oriented channels were evident in the area south of Myrtle Beach in December, 1989 three months after the storm. Channels were typically 0.25 to 1 meter [1 to 3 ft.] deep, 20 to 60 meters [65 to 200 ft.] wide ... In several areas, these features extended offshore for over two kilometers from the beach into water depths of up to 6 to 10 meters [19 to 32 ft.] MLW.

These materials moved offshore and were redistributed to water depths greater than 4 m (13 ft.). Channels, similar to those observed by Gayes near Myrtle Beach, were also documented by Katuna (1991:266–67) for the Isle of Palms, 6km (4 mi.) N of the Engagement Site.

In the months that followed, nearshore beaches recovered some sand. In water depths greater than 4 m (13 ft.), sand and materials that had been transported there by the storm were not returned to the beach system:

The distribution and transport of large construction debris offshore and the identification of on-offshore oriented channels up to two kilometers from the beach in water depths of greater than 7 meters [22 ft.] is strong evidence for transport of significant volumes of sand offshore during the storm....A rapid reworking and recovery of the nearshore landward of the -4 m [13 ft.] contour was observed between December 1989 and May 1990. More limited reworking and infilling of on-offshore oriented channels occurred over the same period seaward of the -4 m [13 ft.] contour. This suggests that sands that were clearly

transported to water depths greater than -4 m [13 ft.] (approximate closure depth for the Grand Strand) had not returned to the nearshore system and may be lost from the beach system [Gayes 1991:110].

Inside Charleston Harbor, sediment cores collected after the storm showed a widespread sand layer several centimeters thick that had been deposited as a result of the storm (Katuna 1991:268). In addition to an intensification of existing processes of offshore sediment deposition, longshore sediment transport was similarly intensified. As Katuna (1991:268) observes: "The large deposits of sand near Breach Inlet, and the storm deposits within Charleston Harbor suggest that southerly transport of sediment was significant during the hurricane."

In summary, ^{210}Pb data shows that by the time Hurricane Hugo hit South Carolina in 1989, the wrecks of *Housatonic* and *Hunley* had already scoured to the Pleistocene clay layer and then been buried by later Holocene layers of sand and silt. Hugo's surge created a huge hydraulic head in Charleston Harbor and local back barrier areas that, when released after the passage of the storm, carried large quantities of suspended sand, sediment and organic materials offshore beyond the 4 m (13 ft.) depth contour. These displaced sediments were not subsequently returned to the beach system. Longshore sediment transport intensified due to the storm and was probably diverted offshore by the jetties. For the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site, therefore, Hugo contributed sediments resulting in additional burial. In view of the processes discussed above, it is likely that Hugo resulted in the net deposit of sediments over the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site.

HUMAN CHANGES TO THE ENVIRONMENT

Multiple human activities have directly and indirectly affected the natural environment of the *H.L. Hunley/US Navy Housatonic Naval Engagement Site*. Because the coastal zone is formed by an unbounded and complex system of energy and material inputs and outputs, even small actions may have large effects on natural environment that surrounds the site.

CHARLESTON JETTIES

Prior to construction of the Charleston Jetties, the entrance to Charleston Harbor lay several miles south of its present location. Under the combined influence of ebb tidal flow and longshore sediment movement, several large sand bars extended more or less due south across the front of the harbor. Ships entering Charleston moved north along the shore of Morris Island before turning west into the harbor (Figure 8.23).

In the 1840s, new classes of deep-draft steamers began to ply the eastern coast of the United States but were unable to navigate the relatively shallow entrance to Charleston. In February 1857, work began to dredge a deep channel directly into the port. With the onset of the Civil War in 1861, however, these efforts halted (Moore 1980:18–20).

Following cessation of hostilities in 1865, plans began again to open a deep and direct path into Charleston. In 1876, General Gillmore of the US Army Corps of Engineers (and who lead Union ground forces during the war; Chapter 2) finalized a comprehensive plan for the improvement of the harbor incorporating dredging and the construction of two large stone jetties. In 1877, initial funding was secured for the project and work commenced (Moore 1981:32–33).

Considering the project size, construction of the jetties proceeded relatively quickly, and by 1882, five years after the project's start, local maps showed that north and south jetties foundations were almost complete (Moore 1980:34). In 1885, the Corps began dredging a channel through the Charleston bar, and in 1888, specifications for harbor improvement were changed to include dredging a navigational channel at least 106 m (350 ft.) wide and 4.5 m (15 ft.) deep at mean low water. At the same time, the outer tips of the jetties were raised to concentrate ebb tidal current that would scour the dredged channel and keep it from clogging with redeposited sand (Moore 1980:36). In 1895, jetty construction was completed and deemed a success (Figure 8.24).

Jetty construction has interrupted prevailing patterns of longshore sediment transport. Diverted by the north jetty, sediments moving southwest and parallel to Sullivan's Island are now redirected offshore where, in deeper water, current speeds diminish. As current speeds diminish, sediment drops out of suspension resulting in a net accumulation of sediments offshore of Sullivan's Island and over the *H.L. Hunley/US Navy Housatonic Naval Engagement Site*.

The interruption of sediment transport southwestwards along the coast has had severe consequences on Morris Island, immediately south of the jetties. Comparisons between historical maps and modern maps indicates that the Morris Island beach has retreated approximately 1,400 m (4,700 ft.) between the 1890s and 1990s (Figure 8.25). The Morris Island Lighthouse which once stood approximately 800 m (2,700 ft.) inshore of the beach now lies 600 m (2,000 ft.) offshore. Sediments that would have otherwise replenished the dynamic system of Morris Island's beach have contributed to the growth of Sullivan's Island and the net shallowing of

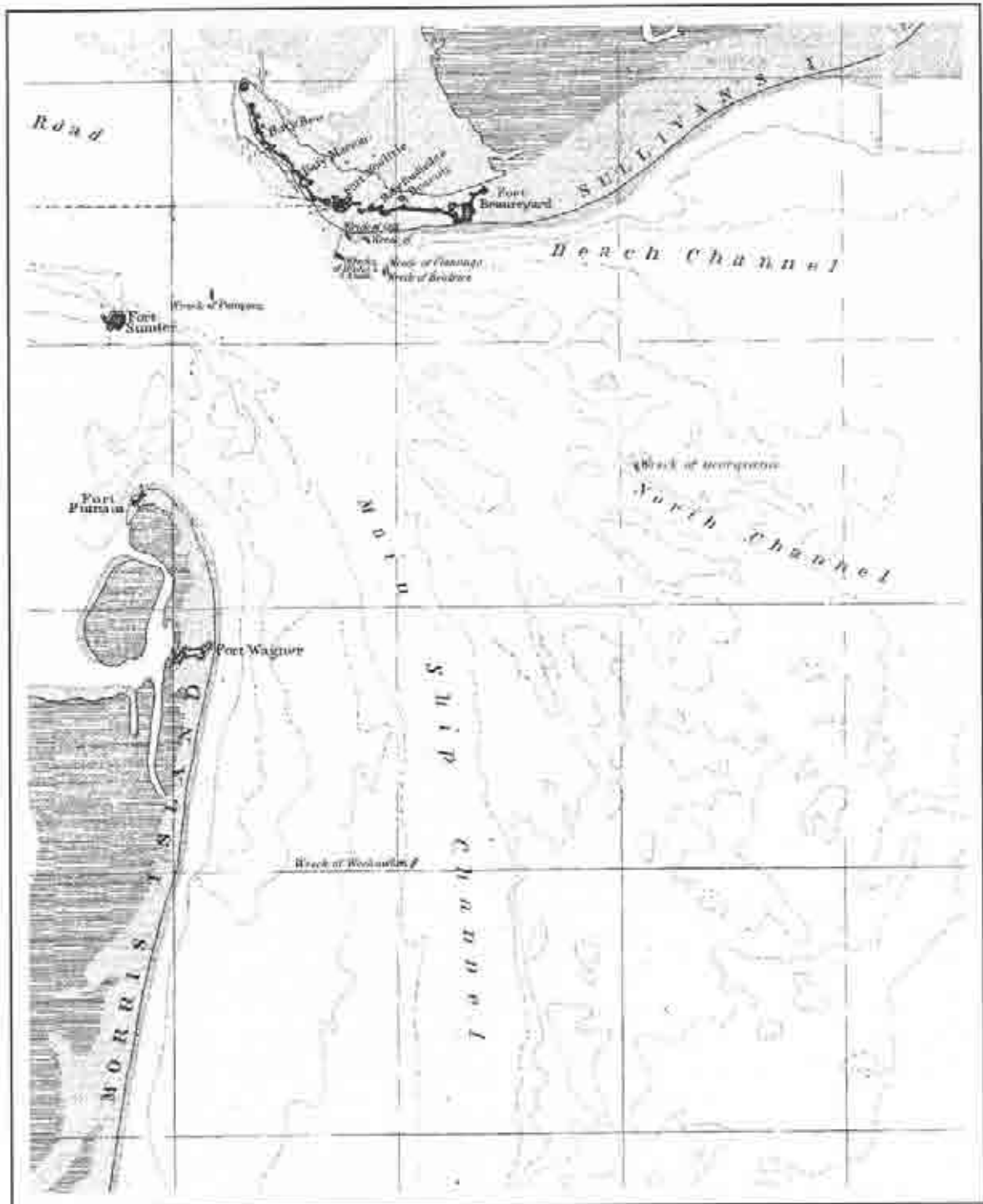


Figure 8.23. Approaches to Charleston Harbor in 1865 (courtesy NOAA).



Figure 8.24. Aerial photograph of the Charleston Jetties (courtesy USGS).

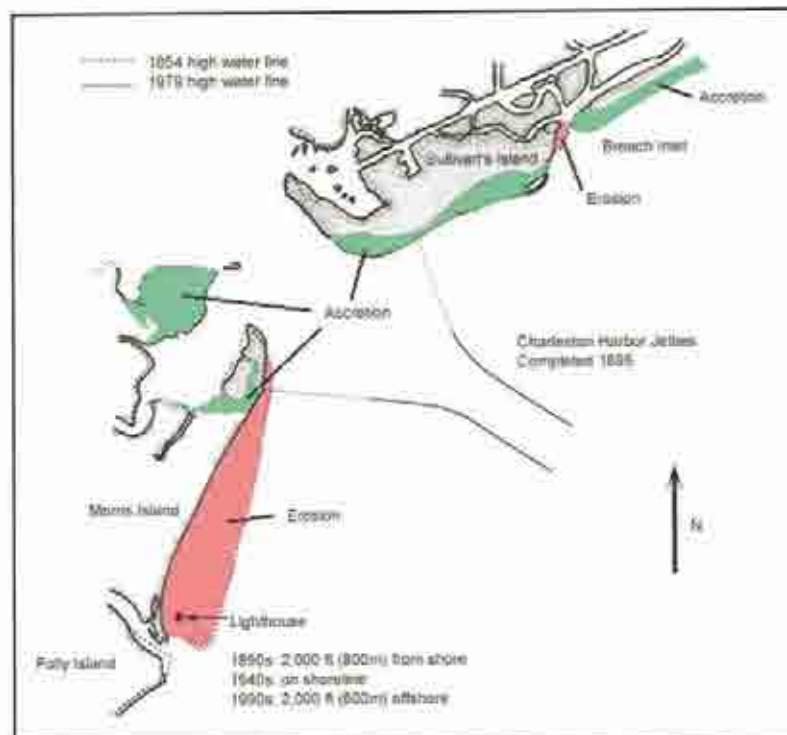


Figure 8.25. Historical changes to the Charleston coast from jetty construction (after Zarillo et al. 1985).

the coastline north of the jetties. As Fitzgerald et al. (1979:9) observe:

Since 1953 most of Sullivan's Island has been accretional with the greatest amount of shoreline progradation occurring on the ends of the island. This buildup at the northeastern end is related to channel shifting at Breaches [sic] Inlet Most of the progradation along the southern portion of the island has occurred after the construction of the north jetty at the rate of approximately 3 m/yr. [10 ft./yr.] . . . a total of 12.3×10^6 m³ [4.3×10^8 ft.³] of sediment was added to the island between 1853 and 1965 which can be attributed to the trapping of the sediment by the northern jetty.

In summary, trapping and diversion of longshore sediment flow have contributed both to the accretion of Sullivan's Island and to the burial of archeological elements of the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site. Rapid sedimentation rates indicated by ²¹⁰Pb dating (Appendix F) can be attributed to the disturbance of a system of movement and deposition that was in dynamic equilibrium prior to the construction of the jetties.

DIVERSION OF THE SANTEE RIVER

Industrial development in South Carolina has a strong historical link to waterways and hydropower. Many major cities in are located at the eastern margin of the Piedmont, where inland waterways cease to be navigable and hydropower for mills and industry is available.

After decades of planning, a project was begun in 1938 to divert the Santee River into the Cooper River to provide water and hydroelectric power for the South Carolina low country. With the completion of the diversion

project in 1941, the Cooper River drainage area increased from 310 km² (1,200 mi.²) to 39,000 km² (15,000 mi.²). With this huge catchment, average flow of the Cooper River increased from 2 m³/sec. (72 ft.³/sec.) to 441 m³/sec. (15,600 ft.³/sec.) (Moore 1981:89).

While the increased river flow provided much needed electric power to regional industry engaged in defense production for the Second World War, it had a dramatic increase on sedimentation rates within Charleston Harbor. The massive influx of freshwater with a huge sediment load did not mix vertically with the heavier seawater in the Charleston Harbor basin. The stratification of fresh and salt water created ideal dynamics for sediment deposition, and thousands of tons of silt began to clog the back barrier channels and shallower arms of the harbor (Moore 1981:89). As early as 1942, dramatic shoaling inside the harbor threatened the economic usefulness of Charleston as a port. Despite an aggressive program of dredging, shoals reappeared quickly after removal, and the harbor turned into a series of narrow channels bounded by wide tidal flats of fine fresh-water sediments. By 1977, construction had begun to return the Santee River to its original drainage via a new hydroelectric plant at Lake Moultrie. By 1985, the Santee River no longer drained into the Cooper River and Charleston Harbor's problems with sediment build-up had abated.

In summary, diversion of the Santee River into the Cooper River dumped millions of tons of freshwater sediments into Charleston Harbor and, presumably, coastal margins adjacent to the harbor's outflow. In addition to increased sediments moved into the area of the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site by direct current action, redistributed dredge spoil was a potential impact on the site as well. Fine freshwater silts dumped on site as a result of the Santee River diversion may be indicated by silty clay and silty sand layers in the upper strata of

vibracores taken around *Housatonic* (Figure 8.13). While this is speculative, an increase in ambient sediment load due to the Santee diversion must, along with the construction of the jetties, be seen as a primary factor in the rapid sedimentation rate indicated by the ^{210}Pb data (Appendix F).

OTHER HUMAN EFFECTS

Commercial Fishing

Shrimp fishing is an important part of Charleston's commercial fishing industry and takes place over the *Hunley/Housatonic* Engagement Site. Because shrimp fishing involves dragging nets over the seabed, they often catch on prominent features standing off the bottom. These "hangs" can damage nets and are therefore tracked and avoided by fishermen whenever possible. Only one hang has been recorded by shrimp fishermen in the area of the Engagement Site, and the reported position agrees well with the observed position of the Third Anomaly (Chapter 4).

Dredging

Dredging to open and maintain navigational channels has been a practice in the Charleston area since at least 1857. Dredge spoil is typically moved offshore by barge and redeposited. As mentioned above, two of the observed Holocene strata in vibracores recovered around the wreck of *Housatonic* may be redeposited dredge spoil.

SUMMARY AND CONCLUSIONS

Research themes developed during the 1996 *H.L. Hunley* Assessment (Murphy 1998; Chapter 3) pointed to natural processes and factors worthy of further examination and development during work on *Housatonic*.

Successful use of ^{210}Pb radiometric dating methods to characterize sediments overlying *Hunley* (Murphy et al. 1998:98–99), showed that these data could shed important light on burial sequences and site formation processes for underwater archeological sites. Characterization of the sediments surrounding *Hunley* by remote sensing and direct examination completed in 1996 lead to research domains worth developing further for *Housatonic*. An environmental characterization of the region around *Hunley* (Harris and Askins 1998) outlined factors of potential importance to the site that deserved detailed analysis.

A complex series of environmental variables ranging from the width and depth of the Continental Shelf to seasonal changes in regional high pressure systems have all had effects upon the *H.L. Hunley/US Navy Housatonic* Naval Engagement Site over a range of time and space. Data and processes discussed above reinforce and amplify conclusions concerning factors relevant to site formation processes drawn as a result of the 1996 *Hunley* assessment (Murphy et al. 1998). After examining multiple lines of evidence Murphy et al. (1998:117) came to the conclusion that: "... *H.L. Hunley* was buried soon after loss, most likely within 25 years. Sedimentary evidence, biological evidence and ^{210}Pb dating indicate the vessel has not been exposed through episodic burial and reburial events." What is now clear is that *Hunley* was not the only component of the site to experience rapid postdepositional burial.

All elements of the *H.L. Hunley/US Navy Housatonic* Naval Engagement Site lie within the same environmental framework, have been subjected the same forces and, as shall be shown (Chapter 9), changed in the same way. Relatively permanent Tertiary geological structures acted as a foundation for more transitory Quaternary sediment deposition around the engagement site. Holocene and Pleistocene strata accumulated in

different areas and with different characteristics as a result of currents, tides and waves acting within the structure of underlying Pliocene, Miocene and Oligocene geomorphology. Geologically rapid sea level changes have moved the areas of Pleistocene and Holocene deposition both on and offshore of the current position of the South Carolina coast.

The Engagement Site lies in an area that was an estuarine or lagoonal (i.e., back barrier) environment as recently as 730,000 years ago. Overlying the clayey sand and sticky gray clay of Pleistocene layers deposited in this back barrier environment are looser unconsolidated Holocene sands and shell layers. Under the influence of tidal currents, *Hunley*, *Housatonic* and the Third Anomaly scoured and settled very quickly through the Holocene sands but the Pleistocene clay stratum acted as a dense and cohesive layer that slowed and eventually stopped the downward scour. The devastating earthquake of 1886 (7.7 on the Richter Scale) may have fluidized the Pleistocene strata supporting archeological elements of the Engagement Site and contributed their further subsidence.

An analysis of vibrocore stratigraphy, sedimentation rates indicated by ^{210}Pb , historically documented changes in bathymetry and coastal geomorphology (corrected for sea level change), an analysis of offshore sediment transport patterns, and a uniform reflector in chirp sub-bottom data at about -1 m (3 ft.) below modern bottom all point to the fact that

the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site has experienced recent and rapid deposition of sediment. The primary reason for this sediment accumulation is the construction of the Charleston jetties that disturbed the dynamic equilibrium of coastal sediment transport and caused extensive deposition over the site. Additional contributory factors, the diversion of the Santee River and dredge spoil deposition, added an extensive sediment load to Charleston Harbor. These sediments may be represented in some of the vibrocores recovered from the site.

Both *Hunley* and *Housatonic* scoured rapidly down to the Pleistocene clay layer following their sinking in 1864. While *Housatonic*'s superstructure rotted, was salvaged, and then dragged to the mudline, *Hunley* was not discovered and thus apparently not directly affected by human actions following sinking. Sediment accumulation, due to jetty construction, completed the processes of burial already started by the scouring of the wrecks, this explains the burial of both elements of the Engagement Site as observed in 1995, 1996 and 1999. Storms such as Hurricane Hugo did not change the existing pattern of sediment deposition over the site but rather intensified it. As with the results of the 1996 *Hunley* assessment, multiple lines of scientific evidence point to rapid burial following sinking and this explains the superior preservation of all elements of the Engagement Site.

CHAPTER 9

Analysis

David L. Conlin

An explicitly delineated research design (Chapter 3) guided field methodology (Chapter 4) that produced specific observations about components of the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site, including *Housatonic*, the Third Anomaly, the Fourth Anomaly (Chapter 5) and, by implication *Hunley*. These observations and the data generated can be augmented with historical research (Chapter 2) and examination of the physical context of the site (Chapter 8) to develop a broadly based analysis of *Hunley*'s attack on USS *Housatonic* and the post attack events and processes that have affected them. The following chapter synthesizes this information and analyzes the historical, archeological and natural forces affecting *Housatonic*, the Third Anomaly, the Fourth Anomaly and *H.L. Hunley*.

Archeological data derived from subsurface probe transects and test excavations support historical accounts of *Housatonic*'s sinking by a massive explosion caused by *Hunley*'s torpedo that destroyed its starboard stern. Despite

multiple salvage and leveling episodes, the *Housatonic* wreck displays a high degree of structural integrity and superior preservation of portable artifacts illustrative of daily life on the Union blockade.

Soon after sinking, *Housatonic* scoured and rapidly settled down through relatively loose, sandy sediments and then stopped at the firmer layer of Pleistocene clay. In 1909, the wreck was leveled to the seabed and, following construction of the Charleston jetties, redirected sediments buried the wreck under at least 4 ft. (1.2 m) of sandy mud.

The Third Anomaly, almost certainly the buoy that marked the wreck of *Housatonic* as a navigational hazard, also scoured and settled to the Pleistocene clay layer and was partially buried. The Fourth Anomaly, a small anchor that cannot be conclusively linked to other components of the Engagement Site, was also buried by diverted sediment flow.

Hunley appears to have survived the attack for at least 50 minutes—long enough to send the blue signal for success to the waiting sentries

at Breach Inlet. *Hunley's* location, as discovered on the bottom in 1995, matches a reported sighting of the blue light quite well and may indicate that signaling the successful attack on *Housatonic* was the one of the last things Dixon and his crew did prior to vanishing for 131 years. Following sinking, *Hunley* experienced the same dynamics of scour, settling and burial that stabilized, buried and preserved the other Engagement Site components.

A tangential study, the geotechnical analysis of sediments surrounding and underlying *Hunley*, showed sediments did not have sufficient strength to make a "box-core" recovery of the submarine feasible, nor would they allow for recovery of the potentially fragile stern features while still encased in their surrounding sedimentary matrix (Chapter 3).

Finally, this chapter will lay out key historical events that occurred sequentially and set the stage for destruction of USS *Housatonic* and will present the attack in a broader political and military context.

USS HOUSATONIC: ANALYSIS

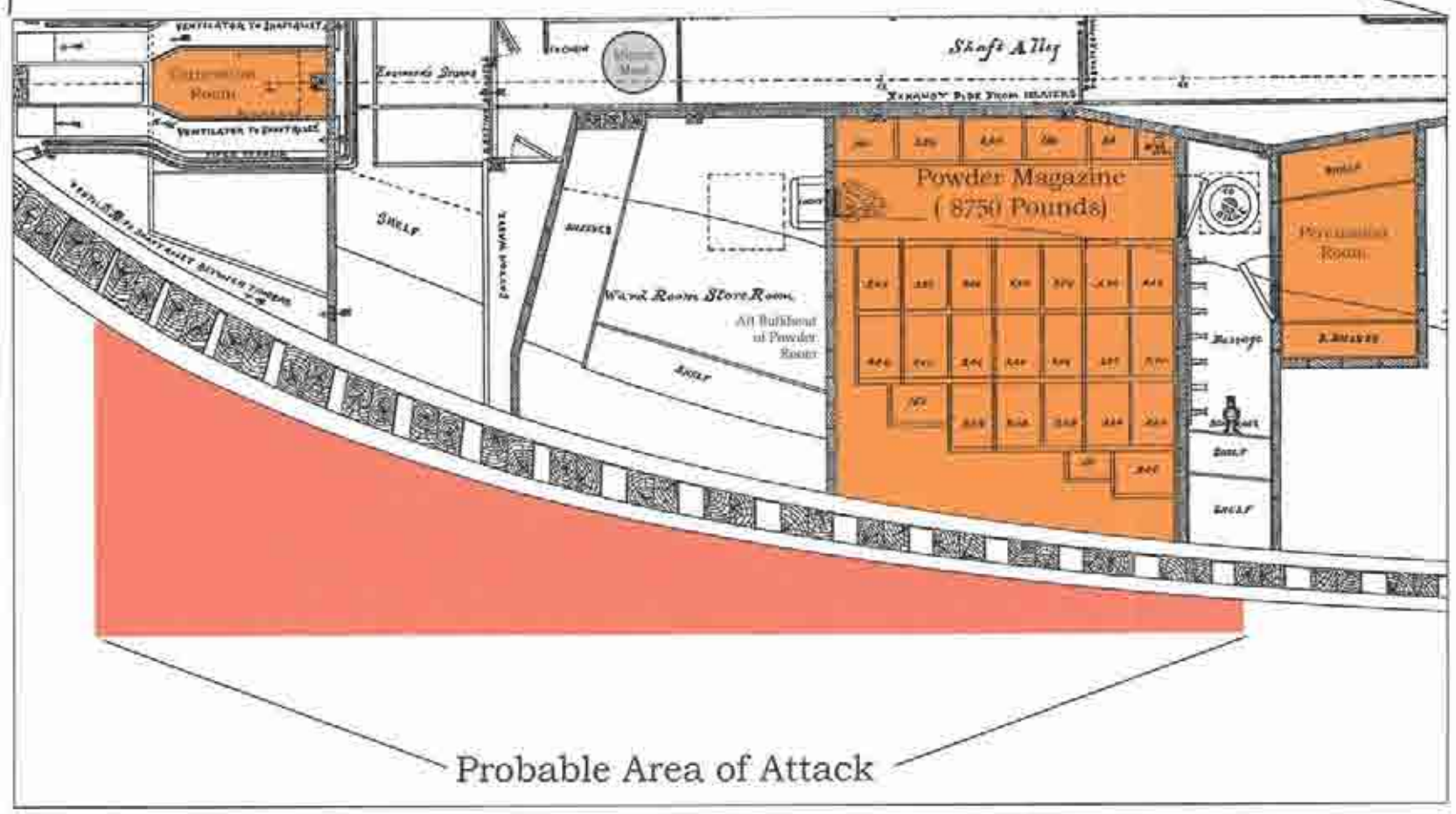
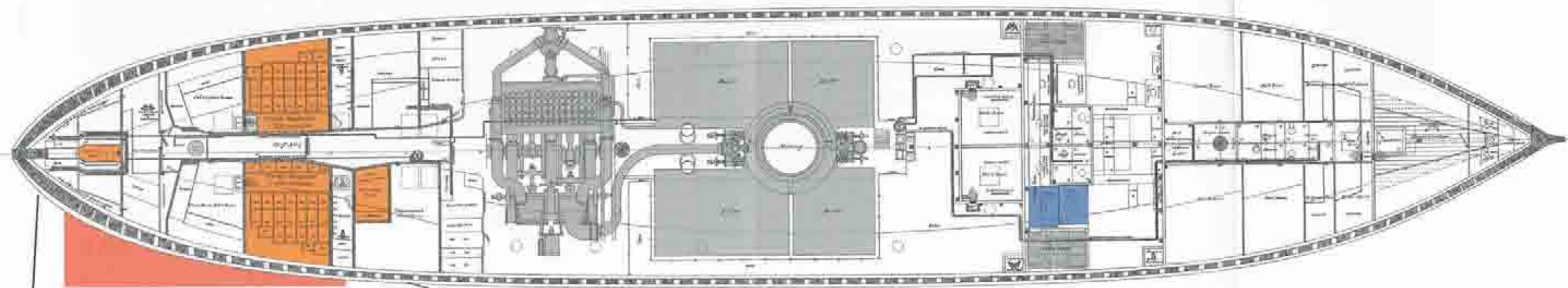
HOUSATONIC HISTORY

Historical accounts from the Court of Inquiry convened following *Housatonic's* loss paint a detailed picture of a well planned and directed attack that placed *Hunley's* 135-pound torpedo to the precise location that would deliver a killing blow. Lieutenant Dixon and his crew capitalized on their advantages of initiative, surprise, and good intelligence to choose the time and position for an effective attack. By the time *Housatonic* lookouts saw the approaching submarine, it was already too late—*Hunley* had already closed to the point where the Union ship's larger guns could not be trained on the submarine. The close range at which the submarine became visible to *Housatonic's* crew meant there was insufficient time to slip anchor

and maneuver out of the way of the attacking *Hunley*. In a very real sense, barring failure of the torpedo, success of the attack was already assured by the time the Union sailors on *Housatonic* became aware that something was wrong.

Fundamentally, the skill and precision of *Hunley's* attack on *Housatonic* mirrored the sophistication of *Hunley* as a weapon and a piece of technology. Armed with good intelligence about the ship, Dixon and his crew probably knew exactly where to strike *Housatonic* to deliver a killing blow.

As *Hunley* attacked, both Master's Mate Lewis A. Corinthwait and Lieutenant F. J. Higgon reported that the submarine changed course, steered parallel and towards the stern of *Housatonic* prior to moving in for the final run into the starboard stern quarter (Bak 1999:161–162). Testimony by both Acting Master John Crosby and John Saunders at the *Housatonic* Court of Inquiry states that *Hunley* slammed home the torpedo in the area of the mizzenmast (Bak 1999:154). The mizzenmast was a convenient aiming point for the attack, and easy to see from the small, water-level view port of *Hunley*. Assuming *Ossipee's* plans are representative of *Housatonic's* interior arrangement, aiming at the mizzenmast would place the torpedo directly between the powder magazine, which could be loaded with up to 8,750 pounds of black powder, and an unspecified amount of guncotton in the guncotton room (Figures 9.1, 9.2 and 9.3). Secondary explosions in either the guncotton room, the powder magazine or both would probably result in sympathetic detonations in the port powder magazine potentially containing an additional 7,250 pounds of black powder, multiplying the effect of *Hunley's* torpedo charge more than a hundredfold. The large column of black smoke reported by Acting Master Joseph Congdon, Lieutenant F. J. Higgon and Acting Master's Mate L. A. Corinthwait at the Court

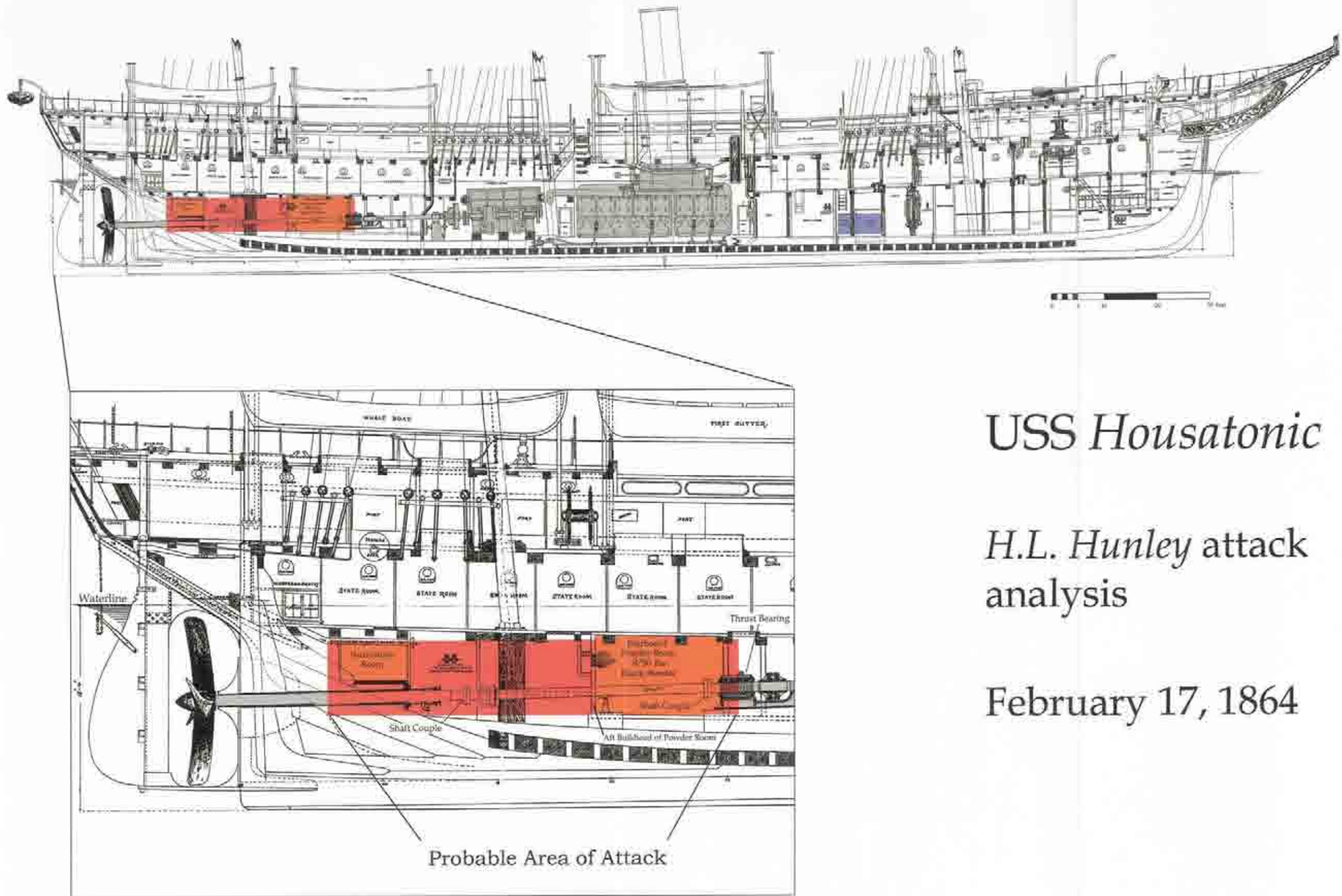


USS Housatonic

H.L. Hunley attack analysis

February 17, 1864

Figure 9.1. Plan View of the *Hunley* Attack.



USS Housatonic

*H.L. Hunley attack
analysis*

February 17, 1864

Figure 9.2. Starboard Side View of the Attack

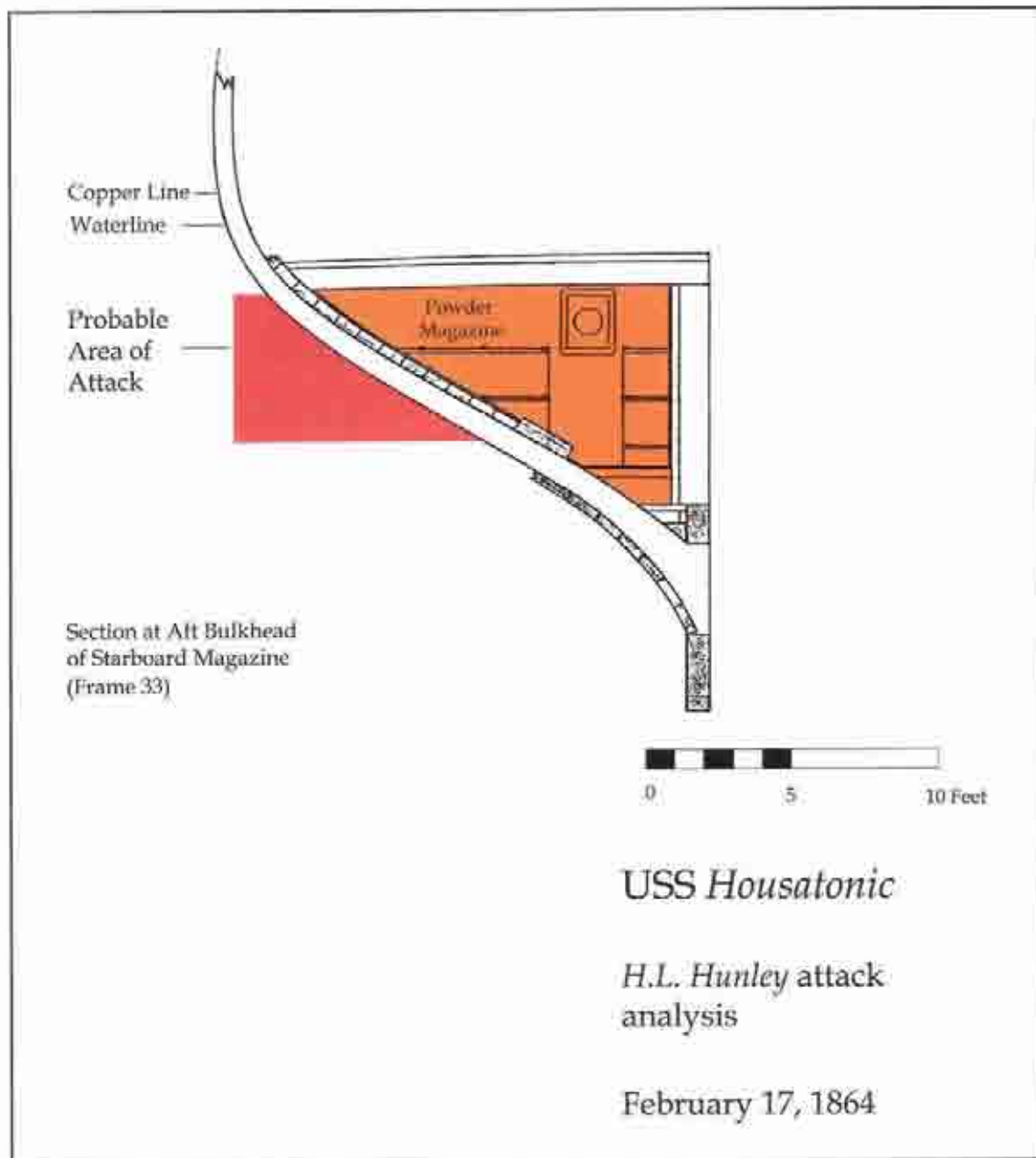


Figure 9.3. Side view of the *Hunley* attack.

of Inquiry may have been the result of the black powder in one or both of the powder magazines detonating, or alternately, the result of seawater dousing the coal fires in *Housatonic's* boilers (Bak 1999:160). Though both black powder detonations and boiler steam are light colored, seen in the $\frac{3}{4}$ moonlight, they may have appeared as "dark" smoke.

As *Hunley* moved in for the attack, Assistant Engineer C. F. Mayer reported that *Housatonic's* engine was moving in reverse. After *Hunley's* torpedo exploded, the engine raced as if the propeller shaft had been sheared (Bak 1999:164). The probable area of attack (Figure 9.2) includes two couplings in the propeller shaft. These couplings joined different sections of the shaft that were manufactured and installed in *Housatonic* separately. While it is possible that the detonation of the charge and secondary detonation of one or both of the powder magazines snapped the shaft itself, because the couplings are the weakest links in the propeller shaft, it is more likely that *Housatonic's* propeller shaft was broken at one or both of the couplings as a result of the attack.

Testimony from the *Housatonic* crew states that the submarine was too low in the water and too close to the ship to bring the ship's large guns to bear when it was finally spotted (Bak 1999:158). In addition to being beneath the large guns, attacking at the stern, where the turn of the hull was most pronounced, protected the submarine from some small arms fire during the time it was closest to the hull. Ensign Craven, for example, reported that he had to lean over the rail to fire at the submarine as it closed under the counter of the hull (Bak 1999:158). Shielded from small arms fire, Dixon was able to press the assault home, and this certainly contributed to the overall effectiveness of the attack.

In contrast to the October attack by *David* against *New Ironsides*, observers on *Housatonic* reported that there was no water plume from

Hunley's torpedo explosion—evidence that the explosion was dampened by the ship's hull and or the water depth at which the charge was delivered. The force of the explosion was not dissipated upwards, but instead was directed into *Housatonic's* interior, indicating a precise charge placement well below the waterline beneath the hull where it would have maximum effect. On February 20, 1864, just three days after the attack, *Canadiagua's* Captain, Joseph Green, reported the after part of *Housatonic's* spar deck appeared to have been entirely blown off (Official Records of the Union and Confederate Navies in the War of the Rebellion [ORN] ser. 1:15:331). Ten months after the attack, on November 27, 1864, Lieutenant Churchill's salvage divers reported that all bulkheads aft of the mainmast were completely demolished—further evidence of the explosion's effectiveness and the manner in which it propagated through the ship (ORN ser. 1:15:334).

Acting Master Joseph Congdon's and Master's Mate L. A. Corinthwait's eyewitness accounts reported pieces of deck thrown into the air as high as the mizzenmast top. Ensign C. H. Craven reported the entire starboard side of the quarter deck aft the mizzenmast as well as furniture from the wardroom were floating, and he surmised that the whole starboard side of the ship aft of the mizzenmast had been blown off (Bak 1999:160–161)—all evidence that the explosion's force exceeded that expected from the torpedo charge alone.

Beyond eyewitness accounts, there is indirect historical evidence that the explosion was well placed and larger than the torpedo charge. All accounts agree that *Housatonic* sank three to five minutes following the explosion. In three to five minutes, enough water was taken onboard to sink a 205-ft. (62.5 m) long ship of almost 2,000 tons displacement, and this argues persuasively for massive damage to *Housatonic's* hull integrity resulting from the attack.

Tactically, the calm seas of February 17 were necessary to allow the four-mile approach from Breach Inlet for the relatively underpowered submarine. Moreover, it is plausible that, following the attack, *Hunley* may have been waiting for the tide to change before attempting to return to shore when events overcame the crew and sent the submarine to the bottom for the third and final time. The second full moon of 1864 was February 22, and on February 17, it was more than $\frac{3}{4}$ full. The bright moon had a mixed tactical effect: it allowed the attacking *Hunley* to clearly distinguish the anchored *Housatonic*, yet, at the same time, allowed the Union lookouts to see the submarine as it closed to attack. Had Dixon waited for a darker night, the submarine might not have been spotted until it actually drove the torpedo home. Had the submarine not been spotted until it had effectively placed its torpedo at or adjacent to the powder magazines, it might have escaped unscathed from the encounter and made it safely back to the lighted beacon fire at Breach Inlet.

Tidal flow through breaks in the barrier islands reach their maximum rate during periods of full and new moons (Chapter 8). A strong outgoing tide may have assisted Dixon and his crew in reaching the softer, more easily damaged targets of the outer blockade line, but it would have necessitated a wait for the incoming tide to return to shore after the attack. This may explain the observed proximity of *Hunley* to the wreck of *Housatonic* following the attack—the submarine was awaiting the incoming tide when it sank.

HOUSATONIC ARCHEOLOGY

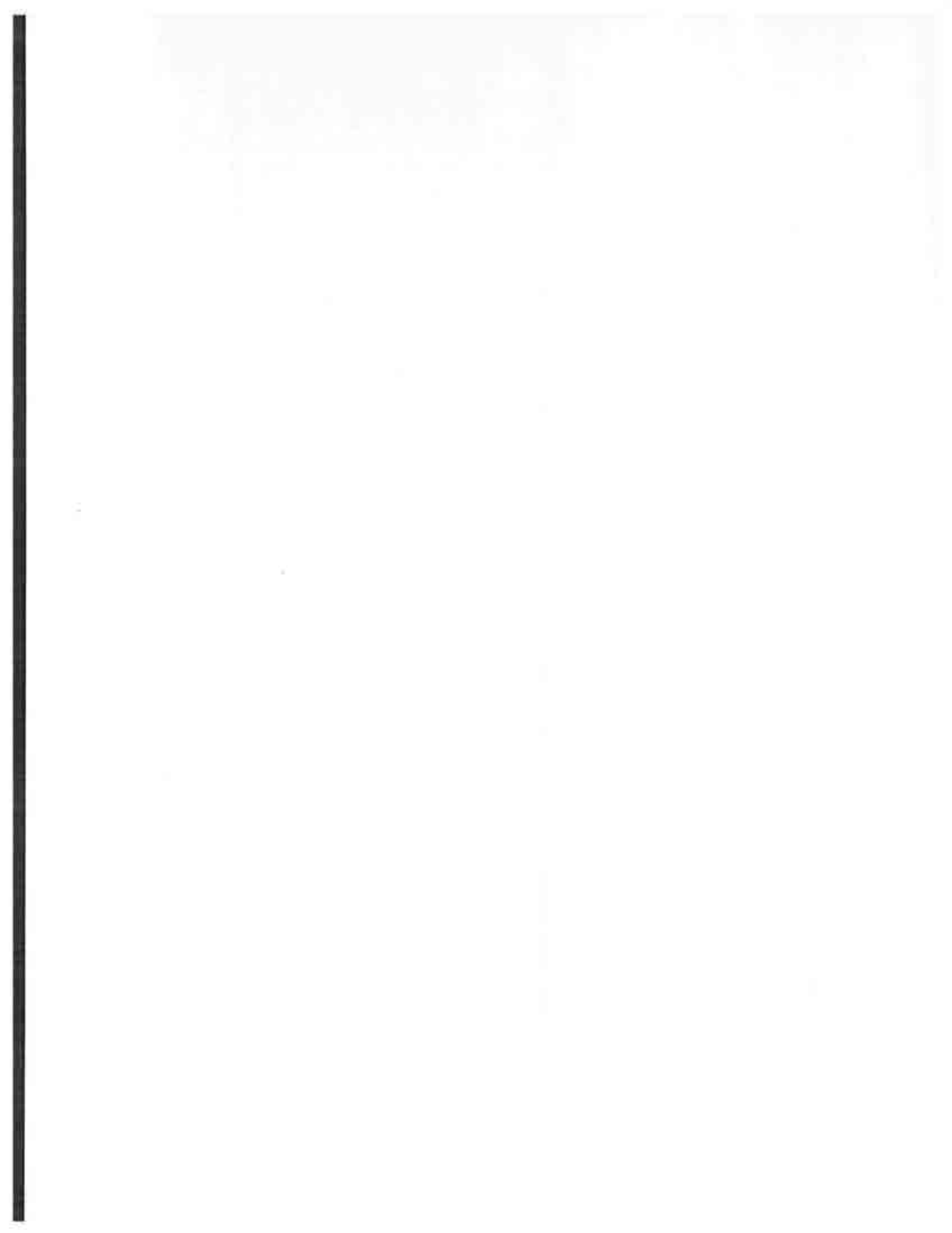
Data produced during the *Housatonic* assessment provide part of the information necessary for the archeological documentation of the wreck that is critical to a comprehensive understanding of the first successful submarine attack in history. *Housatonic*'s orientation, as

inferred from the tanks in Trench 2 (Chapter 4) combined with probe data, indicates the starboard stern quarter of the wreck is either displaced to port or missing, most likely as a result of *Hunley*'s attack. This alteration to *Housatonic*'s hull provides material evidence about the nature and effectiveness of the explosion and the attack available from no other source.

Plans of *Housatonic*'s sister ship USS *Ossipee*'s bilge indicate the two iron tanks that were the principal features of Trench 2 are probably water tanks originally situated in the forward bilge (Figure 9.4). The probe data support these tanks being on the starboard side (Chapter 4). Because the location and orientation of the water tanks is known, both in relation to the ship as originally constructed and in relation to the rest of the archeological site (Figure 9.5), inferences can be drawn about *Housatonic*'s hull orientation and integrity, in particular that a large section of the starboard stern is missing or displaced. Altogether, there are seven possibilities that could explain this observation.

The first explanation is that alignment of the wreck, as determined by orientation measurements of the water tanks is incorrect. This could be the result of the water tanks being displaced relative to their original position or because the tank orientation measurements were not accurately made. It seems unlikely that both water tanks would retain their orientation to each other, both horizontally and vertically, and to the small sections of wooden structure observed in situ if they were disarticulated. To determine conclusively whether the water tanks are displaced from their original position or not would require much additional excavation, both in the vicinity of Trench 2 and in other areas of the hull.

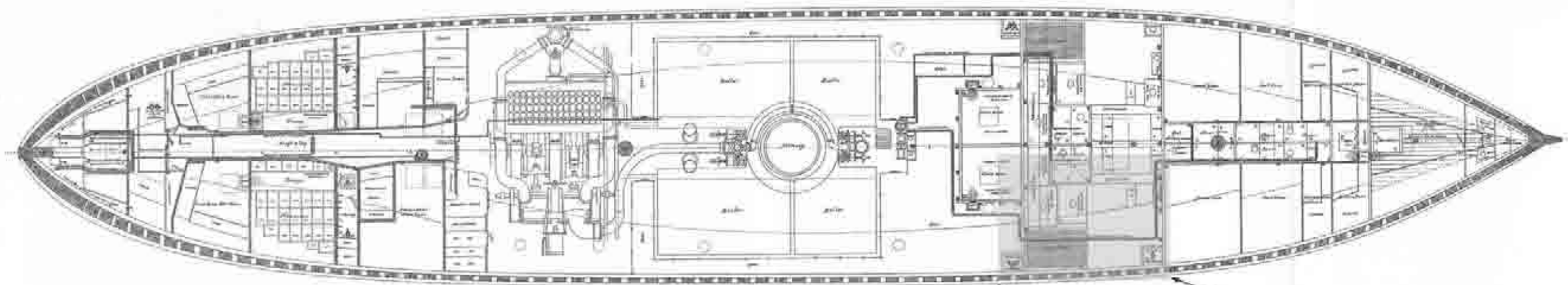
A second explanation could be the orientation measurements are inaccurate. It is likely, however, that the tank orientation



USS HOUSATONIC

TRENCH 2

LOCATION ANALYSIS



0 10 20 30 Feet

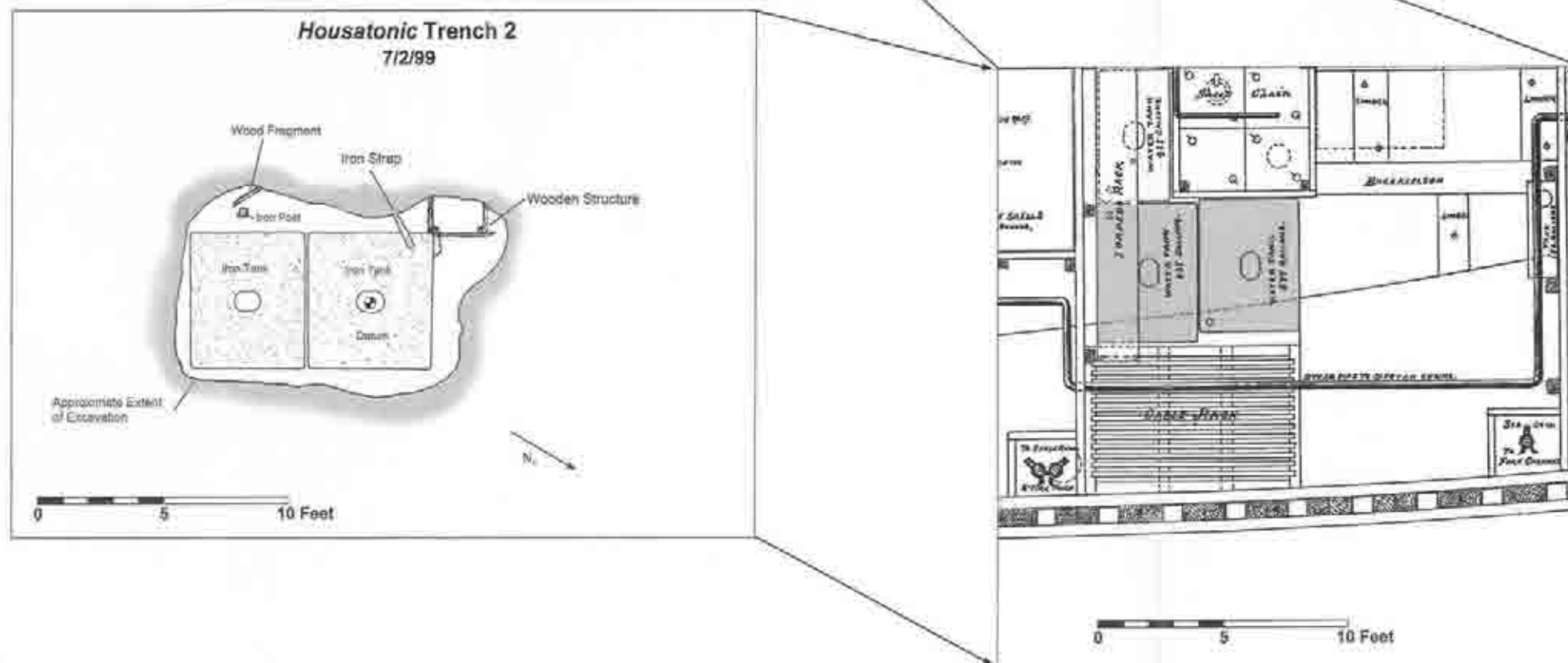


Figure 9.4. Trench 2 Location Analysis

USS Housatonic Site Probe Lines 1999

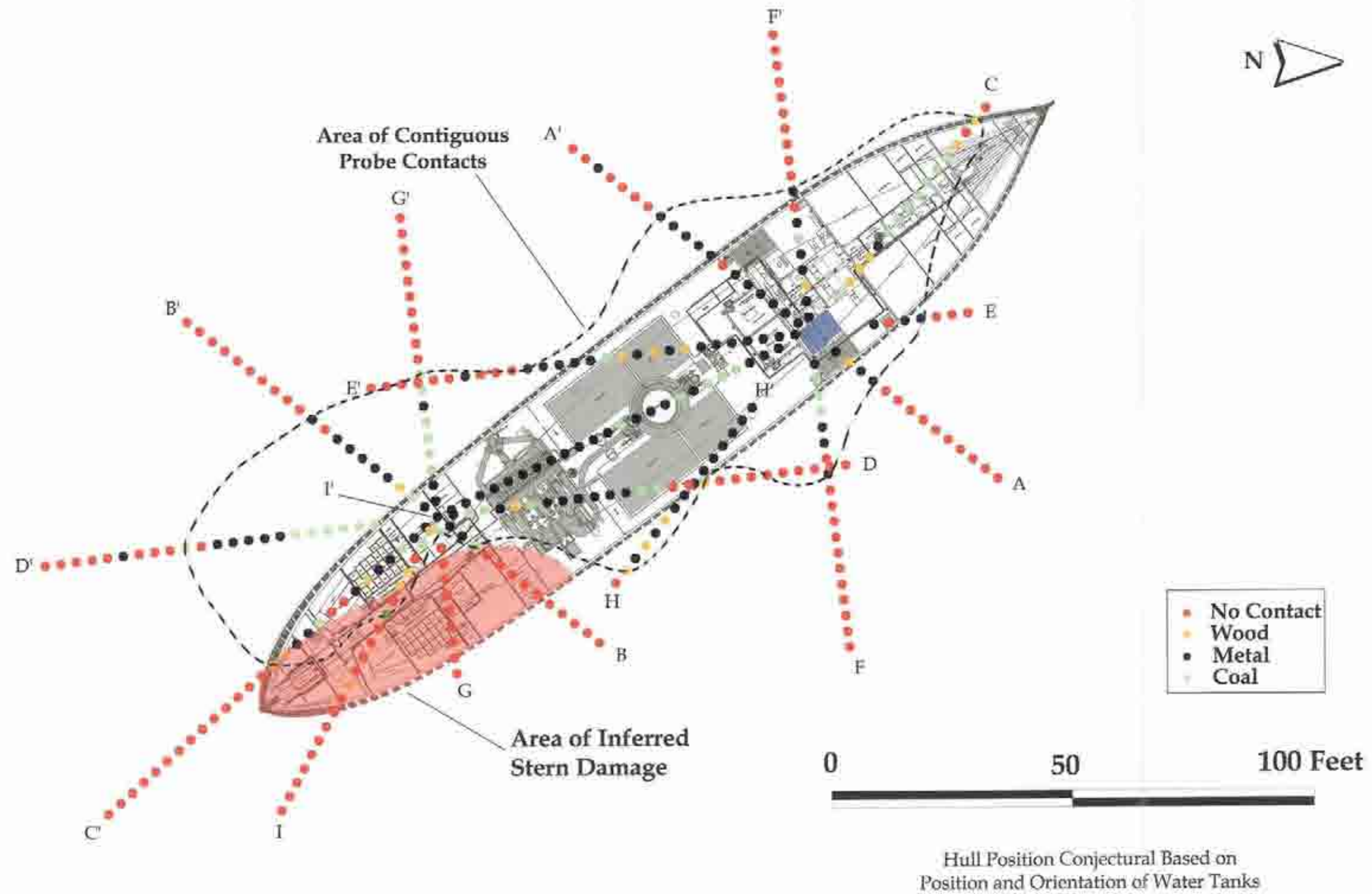


Figure 9.5. *Housatonic* Probe Lines and Wreck Location

measurements are accurate. *Housatonic* hull orientation as based on field measurements is independently supported by historical sources. In testimony at the Court of Inquiry following *Housatonic*'s loss, Acting Master John H. Crosby reported that *Housatonic* was anchored at the time of the attack and lying northwest by west, $\frac{1}{2}$ west, or approximately 298° magnetic. The measured orientation of the water tanks in situ was 62° and, because this measurement was of a section of the tanks perpendicular to the centerline, adding 90° to the measurement gives the present wreck orientation as lying on a magnetic bearing of 332° to 152° with the bow to the north. Adjusting the measured reading for an annual increase in magnetic declination of 7 seconds allows the archeologically measured heading of 332° to be translated to an equivalent 1864 heading of about 316° . In short, the 316° archeologically observed hull orientation accords very well with the historically recorded orientation of 298° . General congruity between the observed and historical hull orientation supports the inference that the ship settled rapidly after the blast, and postdepositional currents, storms and salvage have had little effect on the wreck.

Probe data analysis (Chapter 4) supports the inferred *Housatonic* hull position and orientation based on water tank observations. Probe analysis involved overlaying scaled ship plans onto the probe transects and rotating them to align with historical and observed bearings to see which encompassed more metal or wood contacts. Most metal and wood contacts, 79.5 percent (98 out of 131), fall within the inferred hull orientation based on field observations (Figure 9.6). This number does not include contacts for coal, which do not indicate ship's structure. If the inferred hull orientation is rotated to bring it more into agreement with the historical account (i.e., moved from 316° to 298°), the net effect is to shift the stern position

more to starboard, which diminishes the number of wood and metal contacts contained within an outline of the hull. Shifting the stern to port to encompass outlying contacts ignores evidence for orientation furnished by the water tanks and reduces the number of metal and wood contacts encompassed within an outline of the hull to 69 percent of the total number recorded. Splitting the difference and aligning the hull with the stern more to starboard halfway between the position as determined by water tank orientation and the outlying metal and wood probe contacts to starboard has the net effect of raising the number of metal and wood contacts encompassed within an outline of the hull to 72.5 percent of the total wood and metal contacts recorded. Keeping the water tank where it is on the original ship's plans and rotating an overlay centered on that point, there is, in fact, no way to orient the original outline of the hull to encompass more metal and wood contacts than the orientation as determined by the angle measured for the water tanks.

A third possibility that could affect the hull orientation inference is that the probe line plots are off. The methodology used to establish probe transect line orientation (Chapter 4) produces inherent uncertainty. However, the probe lines form an interlinked network and a comprehensive data set that should be examined as a whole. This data set is both self-reinforcing and robust. The degree to which an orientation error would affect the data set depends upon the angle that the probe line intersects the inferred position of the original hull as measured during fieldwork. For example, where a probe line lies perpendicular, or nearly perpendicular, to the hull side (Figure 9.5), even a large error in orientation for the probe lines would have little effect on the resulting agreement between the probe data and hull position, that is, it does not markedly increase or decrease positive wood or metal contacts. In other cases (Figure 9.5), probe line orientation errors could place

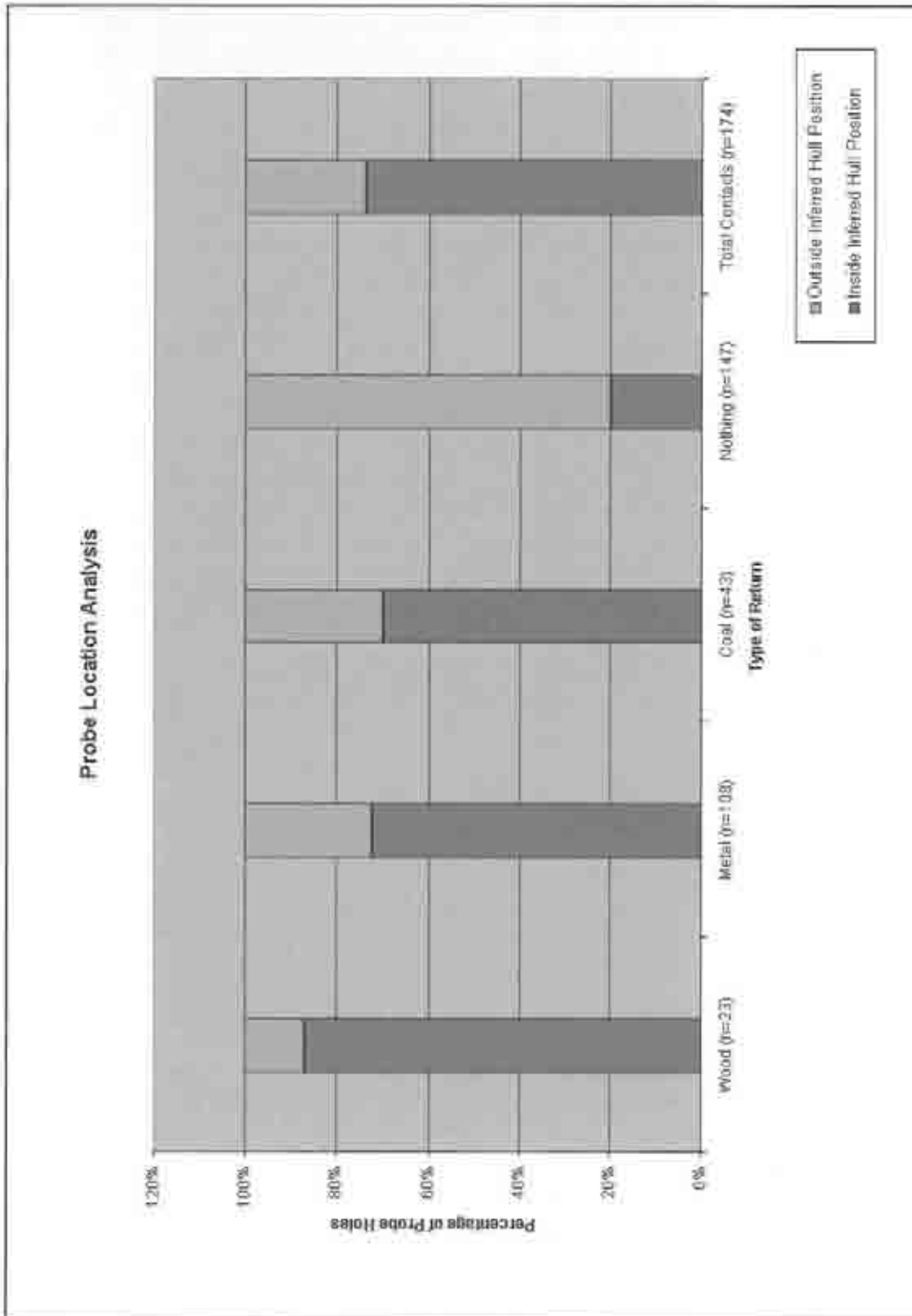


Figure 9.6. Probe location analysis.

more metal returns either within, or outside the inferred outline of the original hull. The net effect of an error in probe line orientation would not change the basic results of the probe data nor address its most interesting findings—the absence of the starboard stern quarter as indicated by the lack of wood or metal contacts in this area along probe lines B, G and I (Figure 9.5).

A fourth possibility affecting the hull orientation inference and its implication of hull damage is that the area of the starboard stern lies buried deeper than could be reached by the probe. This possibility can be discounted because major hull structure was documented by probing in all other areas of the site. Geomorphology supports the unlikelihood of the stern being deeper than the rest of the site due to the lack of vertical relief in the major structural units in the sediment layers (Chapter 8). It is, therefore, unlikely that *Housatonic*'s starboard stern quarter has settled into a depression in underlying sedimentary strata or some sort of unique scour pocket.

A fifth possibility is that marine borers or shipworms such as *teredo navalis* destroyed the ship's stern. This explanation does not account for the lack of coal or metal returns in the stern nor the fact that wood was documented on transects I and C (Figure 9.5). At any rate, it would be difficult to explain the differential destruction of wood only in this particular region of the wreck and not in other areas.

A sixth possibility is that portions of the stern was destroyed in the attack. As discussed above, historical accounts of *Housatonic*'s final moments state without variation that *Hunley* rammed its torpedo into the Union ship on the starboard side near the mizzenmast. The size of the explosion and its observed effects make this the most likely possibility. According to Ensign Charles Craven's testimony at the Court of Inquiry, his impression was that the whole starboard side of *Housatonic* aft of the

mizzenmast was blown off by the attack, and Captain Green's report of February 20, 1864, stated that it appeared that the entire after part of the spar deck had been blown off (Bak 1999:159; ORN ser. 1:15:331). If *Hunley*'s torpedo ignited secondary explosions in one or both of the powder magazines as well as the guncotton and/or percussion rooms, then damage of the apparent magnitude indicated indirectly by the probe lines would be the probable result.

The final possibility is that the stern of *Housatonic* is disarticulated from the rest of the wreck and shifted to the port side. This could be the result of the attack, subsequent salvage and dragging, or both. *Housatonic* was salvaged over the course of 1864–1865, and Captain Ludlow's report as to the wreck's state in 1870 stated the stern had been blown off and portions of machinery recovered from the wreck (Miscellaneous Wrecks, 1871–1888, RG 77, file #1125, National Archives, Southeast Region). Throughout 1873 and into 1874, Benjamin Maillefert's divers salvaged the wreck, and in 1909 William Vierden blew up and dragged the wreck (Maillefert's Salvage logs, South Carolina Historical Society; Annual Report of the Chief of Engineers 1909:1316). By November 1864, 10 months after the attack, Lieutenant Churchill's divers reported that *Housatonic* had settled into the sand about 5 ft. (1.5 m) and was very much rotted away (ORN ser. 1:15:334). If explosives were used to assist with salvage, (as they were to remove the wreck as a navigation hazard in 1909), it is unlikely that the hull would have shifted as a whole, given the dual forces of burial and the resulting suction of the surrounding sediment.

William Vierden dragged *Housatonic* in 1909, 45 years after sinking. If the stern was not shifted to port as a result of the attack, it is possible that this dragging operation caused it. Structurally, because of their narrow cross

sections and the way that timbers articulate, a wooden ship's bow and stern are areas of weakness. Weakness at the stern of *Housatonic* would have made it vulnerable to damage by dragging, and this could have been exacerbated by existing structural damage caused by *Hunley's* attack. Archeologically, three copper-alloy drift pins recovered from Trench 3 show bending that must have been the result of either the explosion or subsequent dragging. Dragging seems more likely because they are bent from a slower force and not broken as from a shock (Figure 9.7).

If the stern is partially destroyed and not simply out of alignment, then materials located during probing operations outside the inferred hull position would have to be interpreted as the probable results of salvage activities, particularly dragging, that are reported in the

historical documents. Presently, there is insufficient data to determine if probe returns off the inferred port stern are coming from displaced structure or from redeposited materials from salvage and dragging. A test excavation for port-side hull timbers at the stern, outside the inferred hull position where probing encountered buried materials would be necessary to answer this question. If the stern is displaced, it could be due to *Hunley's* attack, subsequent dragging, or a combination of both. Beyond extensive excavation, there is no test to distinguish between the three causes of a potentially displaced stern.

Conclusion

Systematic probe analysis has provided strong evidence for orientation and integrity of



Figure 9.7. Bent copper-alloy drift pins (Hunhou 99-083, 99-085 and 99-087). NHC photo by Claire Peachey.

Housatonic's hull, as well as indicating extensive stern hull damage likely from *Hunley*'s attack on February 17, 1864. The nature of materials lying off *Housatonic*'s port stern is unknown, though an additional test excavation in the area just to port of the inferred original position of *Housatonic*'s stern could produce definitive answers to this question. Further probing and excavations, particularly in the stern region could produce additional information that would support or refute the conclusions arrived at here.

HOUSATONIC SITE FORMATION PROCESSES

Salvage

Historical records show that salvage operations began almost immediately following *Housatonic*'s sinking. Initially, materials recovered were probably those easiest to reach and least affected by immersion; i.e., durable equipment on the top decks as well as tackle and rigging. As salvage grew more difficult and the expensive services of divers were required to get to more inaccessible materials, the priorities chosen offer an insight into what was perceived as important by the Union blockade in early 1864. On February 26, nine days after the attack, Commodore Rowan specifically mentioned the ship's guns as items to recover in his orders authorizing the allocation of divers and boats for salvage (Record Group 45, M625, Area 8, Reel 208, National Archives).

Altogether, *Housatonic* carried 16 guns ranging from a 100-pound Parrot to a 12-in. howitzer, and these were apparently the first items salvaged. Historical sources only attest to recovery of six of the 16 guns on the ship. By March 15, 1864, divers had salvaged the two "pivot guns" (probably the 100-pound Parrot and the XI-in. Dahlgren) as well as the four 32-pound smoothbores. Recovery equipment was expensive, however, and the officer in charge

recommended leaving the three 30-pound Parrot guns (letters received by Squadron Commanders, National Archives). *Housatonic* salvage records say nothing of the remaining 10 guns. The three howitzers were mounted in the ship's boats, and those that were sunk with *Housatonic* may have been recovered in the days that followed. Their small size would have required only minimal recovery equipment. The other guns were probably recovered in the course of the salvage operations, which continued until March 1865. In summary, historical sources state that six of *Housatonic*'s 16 guns were salvaged, and it is possible, though unlikely, that one or more of the 10 guns unaccounted for still lie somewhere on the wreck.

Another salvage priority was shells from the ship's magazine. Lieutenant Churchill's work on the wreck in November 1864 focused on the magazine, but it was thwarted by bad weather and swells (ORN ser. 1:15:334). On March 1, 1865, divers retrieved the paymaster's safe, and this seems to be the last work directed at recovering useful articles (as opposed to scrap metal) from the wreck (letters received by the Secretary of the Navy from Squadron Commanders, National Archives).

Early salvage work did not destroy the entire wreck structure—enough of the ship stood proud on the bottom after eight months to foul USS *Mingoe* on September 24, 1864 (ORN ser. 1:15:688). Historical accounts indicate that marine borers rapidly destroyed the ship's wooden structure. In November 1864, 10 months after the attack, Lieutenant Churchill's divers reported that the wreck was "very much worm-eaten" (ORN ser. 1:15:334). By April 1870, six years later, Captain Ludlow of the Corps of Engineers reported that the: "...wooden sheathing inside and the planking outside are eaten by worms down to the copper" (Miscellaneous Wrecks, 1871–1888, RG 77, file #1125, National Archives, Southeast Region).

Rapid hull destruction may be in part explained by wartime shipbuilding practices. Forced to build a fleet to enforce a blockade that in 1861 was more policy than reality, it is unlikely that the Union enjoyed the luxury of time to allow sufficient seasoning of the ship's timbers prior to incorporation into *Housatonic's* hull. Shipwright Charles Desmond recommended that: "In general it can be said that timber for shipbuilding should not be used sooner than three years after felling" (Desmond 1919:12). These three years dried out the timber and made it less attractive to destructive marine life such as *teredo navalis*, the common shipworm, and a lack of seasoning may partially explain the wreck's rapid deterioration.

By 1873 and 1874, the wreck had been reduced to a source of scrap metal—primarily copper, brass, iron and lead. Professor Benjamin Maillefert's salvage logs for the months of June 1873 and April 1874 detail the recovery of large quantities of these materials. On April 17, 1874, divers on Maillefert's work boat *Josephine* recovered approximately 500 pounds of copper bolts from the wreck, a process that was probably helped considerably by the decay of the wooden structure. These "copper bolts" are almost certainly of the same type as the copper-alloy drift pins recovered in Trench 3 (Figure 9.7). On July 28, 1873, Maillefert reported his divers had recovered "two tanks" (Maillefert's Salvage logs, South Carolina Historical Society). Using *Ossipee* plans as a guide, *Housatonic* probably had six water tanks and a tank for tar, but based on the probe data (Figure 9.8; Chapter 5; Transect A in Appendix C), it seems likely that the two tanks recovered were the portside water tanks, identical to those documented in Trench 2, and originally located southwest of the Trench 2 datum (Chapter 4).

Archeologically, the area documented in Trench 1 bears a striking resemblance to the condition of the wreck as reported by Lieutenant Churchill to Admiral Dahlgren on November 27,

1864: "The cabin is completely demolished, as are also all the bulkheads abaft the mainmast; the coal is scattered about her lower decks in heaps, as well as muskets, small arms and quantities of rubbish" (ORN ser. 1:15:334; Chapter 5). The bottom of Trench 1 was entirely covered with coal and produced a pistol and part of a second. Presence of coal was expected on the wreck of a ship that carried 235 tons of it for fuel, but what was not expected was the crowbar (Figure 9.9), which may have been lost on site during salvage operations. It is interesting to note the close proximity of the crowbar to the paymaster's storeroom in the hold.

Looking at the inferred areas of the original ship close to the Trench 1 datum (Figures 9.10 and 9.11) may explain why the most common artifact recovered in this area was zinc artillery fuses (Figure 9.13). The Trench 1 datum is located in the hold approximately 15 ft. (4.6 m) from the inferred original location of the percussion room where these fuses would have been stored. Pieces of wood with dovetail joints (Figure 9.14) may be remains of crates that originally carried the fuses.

As the wreck of *Housatonic* decayed due to worms and salvage, the upper decks rotted and collapsed. When the decks collapsed, they dumped artifacts into the lower reaches of the ship. This process probably accounts for many of the personal items recovered in Trench 2, which included six shoes and two parts of shoes (Figure 9.15), broken pieces of two different ceramic vessels (Figure 9.16); part of a pistol (Hunhou 99-062); and a portion of a lead pencil (Figure 9.17). Looking at the berth deck immediately above the hold in the area of Trench 2 (Figures 9.10 and 9.12), one can see that this was both the mess and sleeping quarters for *Housatonic's* crew. While it is possible that shoes were carried in the hold, it is far more likely that these were personal items belonging to the crew stored in the lockers near the mess tables. Ceramics and the pistol are also likely

USS Housatonic Site

Probe Lines 1999

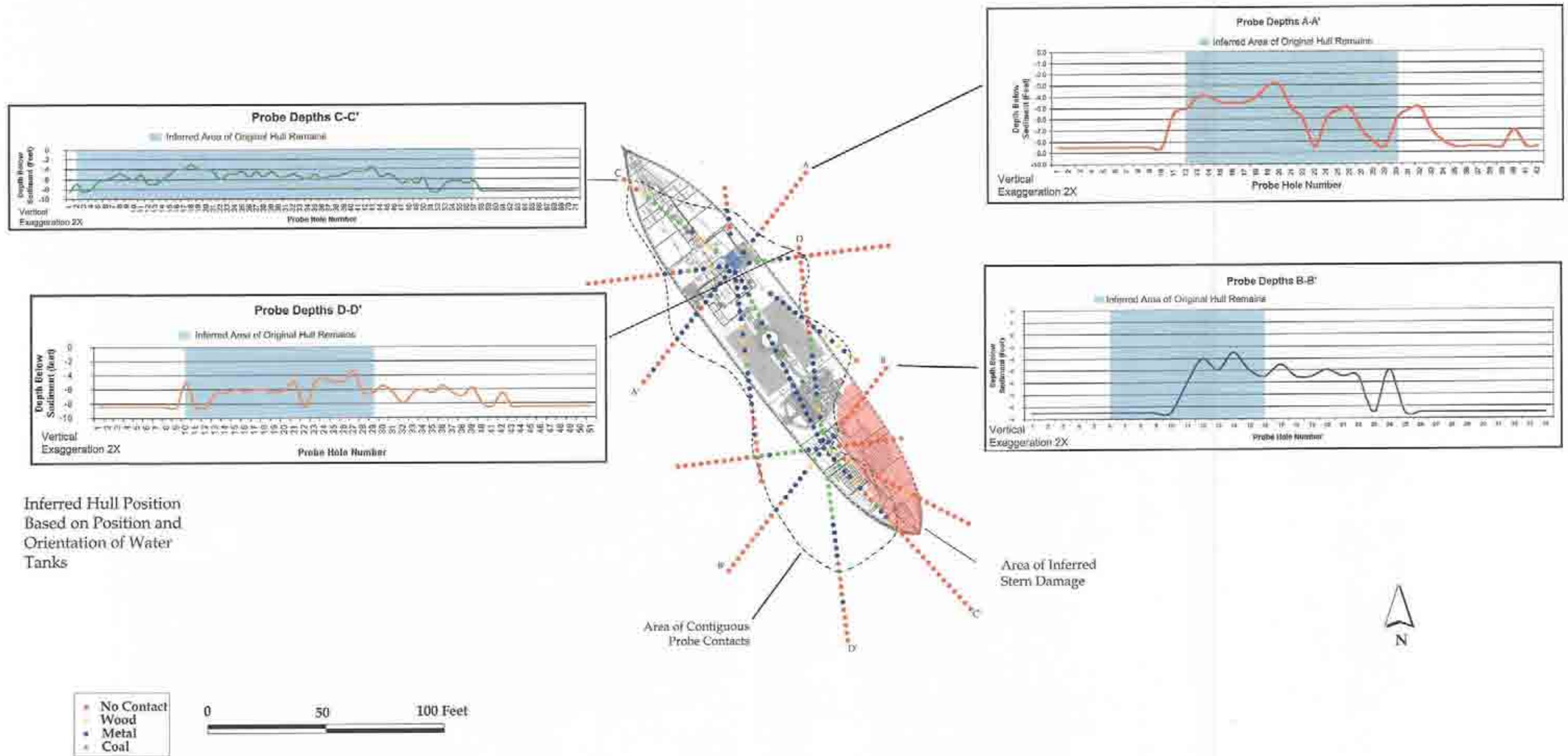


Figure 9.8. Housatonic Site 1999 Probe Lines



Figure 9.9. Bent crowbar (Hunhou 99-038) recovered from Trench 2. NHC photo by Claire Peachey.

to have come from the mess area. Though it is a stretch, the pencil may have come from one of the two desks located on the now missing berth deck within 10 ft. (3 m) of the Trench 2 datum. Another interesting artifact found in Trench 2, the copper-alloy socket (Figure 9.18), is either a stop for the pivot gun races on the main deck or a socket for a railor awning (Chapter 6), either of which is supporting evidence that deck collapse into the hold applied to both the main deck and the berth deck.

Following what was, by historical accounts, relatively low impact salvage work through 1874, *Housatonic's* boilers were dynamited in 1909, and the wreck was lowered an additional 7 ft. (2.2 m) to remove it as a navigation hazard to ships entering and leaving the harbor to the north. By 1909, the principal feature of the wreck still exposed were its two large boilers. Initial attempts by William Virden to bury boiler pieces near the wreck were unsuccessful, and

ultimately about four tons of boiler iron had to be removed from the site to fulfill the terms of the contract between Virden and the Corps of Engineers for hazard removal (Annual Report of the Chief of Engineers 1909:1316). Analysis of the site magnetic contours and probe lines in relation to the inferred location of the original hull (Figure 9.19) may show some indication of Virden's removal and burial of boiler pieces. Data contoured at a 20-gamma gradient interval indicate more iron materials on *Housatonic's* port side than on the starboard. These materials may be boiler pieces that were dragged away from the wreck and either scoured into or were buried in the sediment.

Dragging

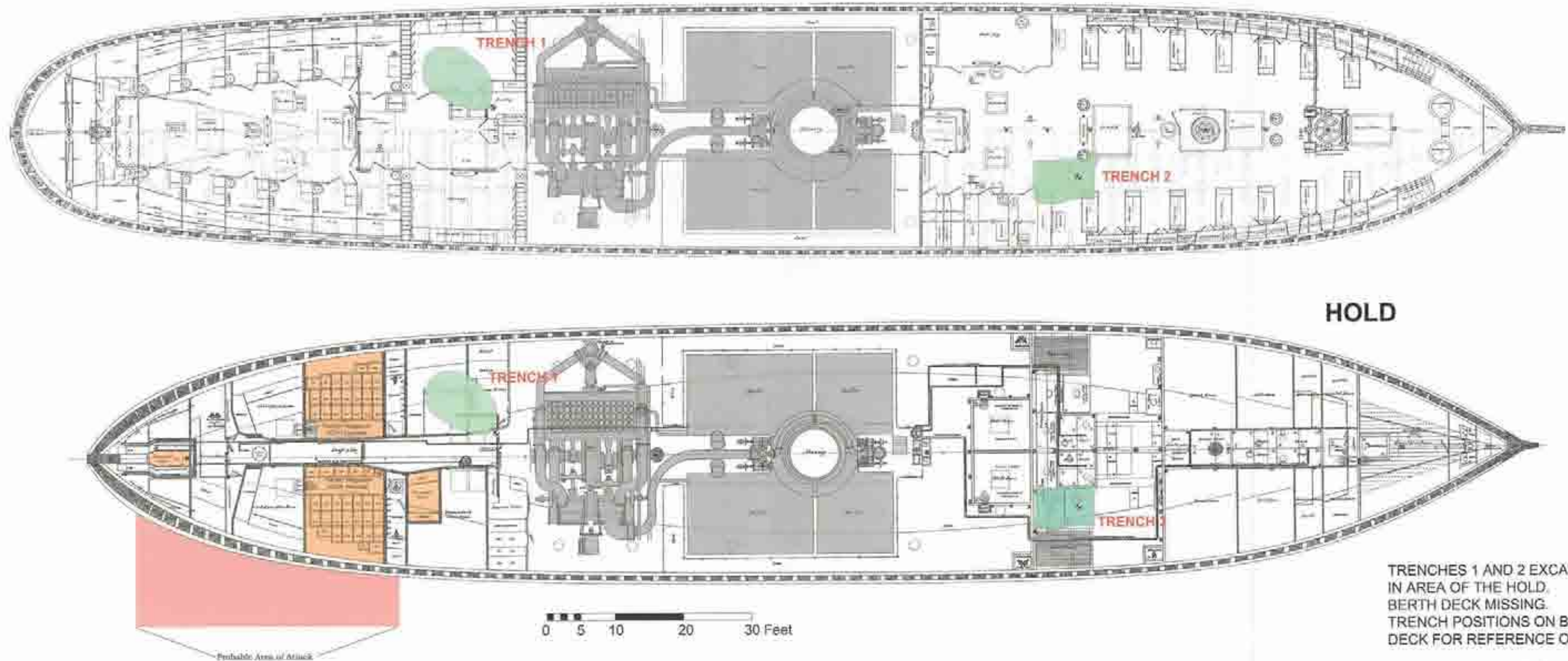
Virden dragged the *Housatonic* area in 1909 as part of his contract to lower the wreck. Dragging would have moved portions of the

USS HOUSATONIC

TRENCH 1 AND 2 RELATIVE LOCATIONS

BERTH DECK

HOLD



TRENCHES 1 AND 2 EXCAVATED
IN AREA OF THE HOLD.
BERTH DECK MISSING.
TRENCH POSITIONS ON BERTH
DECK FOR REFERENCE ONLY.

TRENCH 3 LOCATION OUTSIDE
OF INFERRED ORIGINAL HULL
AREA.

Figure 9.10. *houSATONIC* Trench 1 and 2 Relative Locations

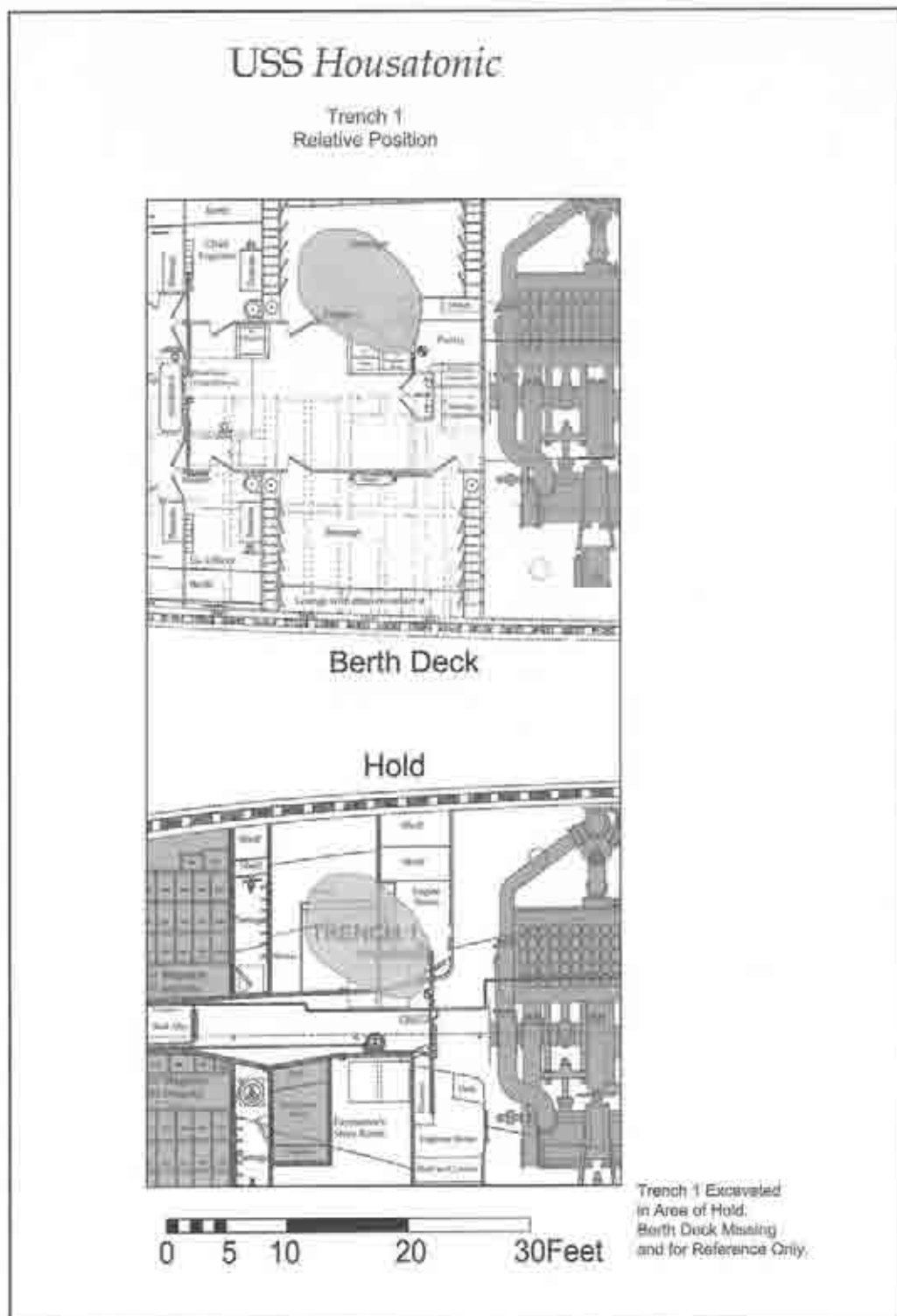


Figure 9.11. Trench 1 relative location.

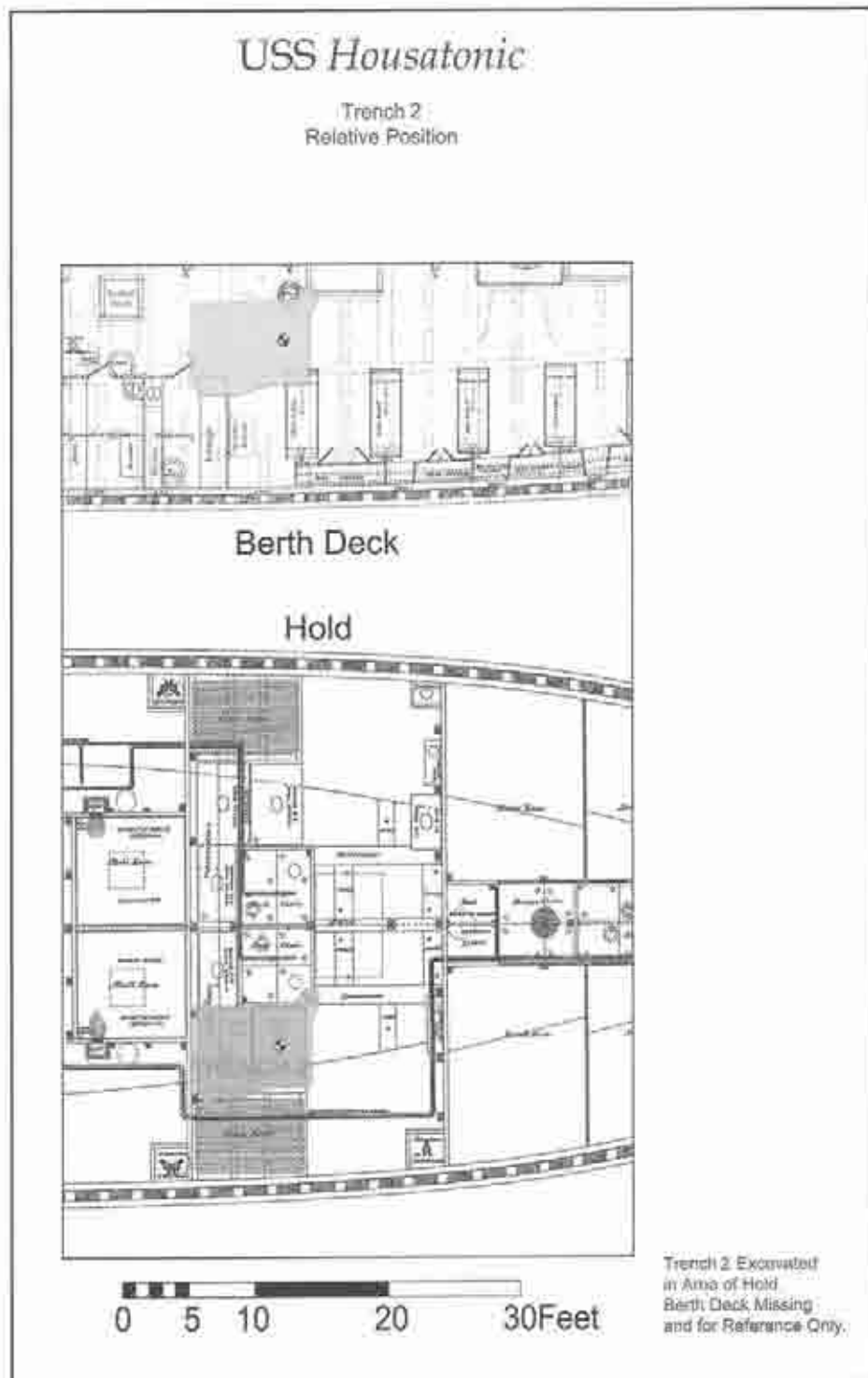


Figure 9.12. Trench 2 relative location.



Figure 9.13. Zinc artillery fuse, probably for a 30-pound Parrott. NHC photo by Claire Peachey.

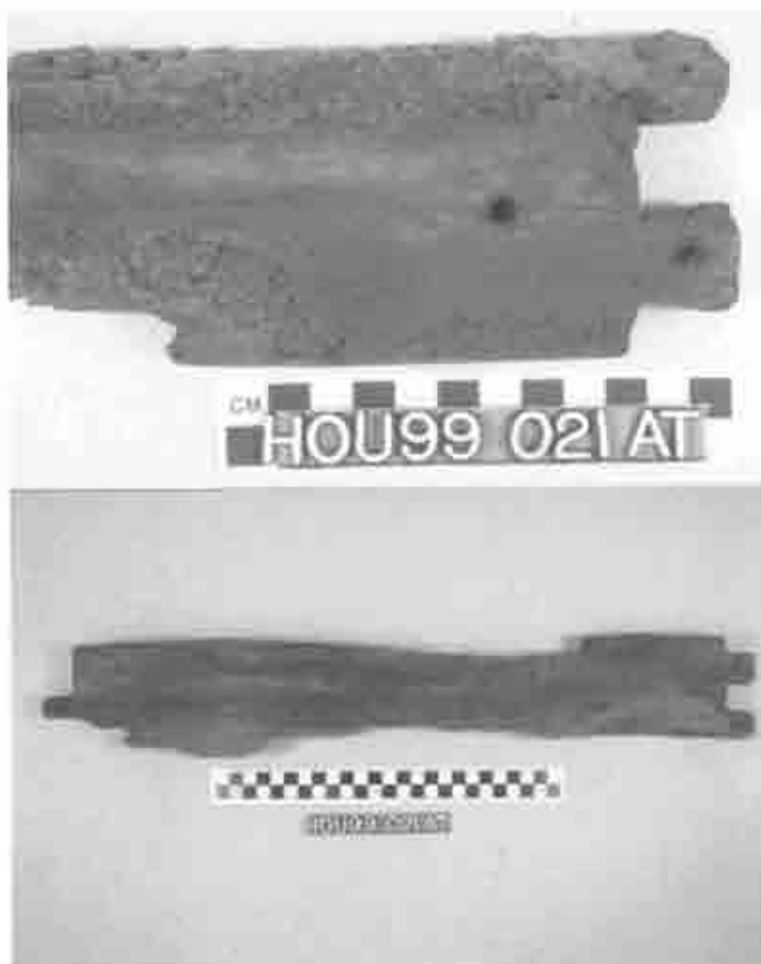


Figure 9.14. Wooden box with dovetail joints. NHC photo by Claire Peachey.

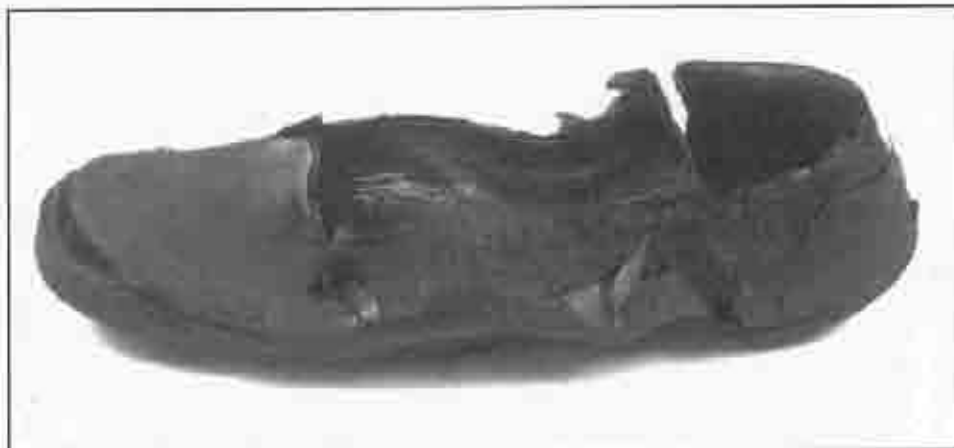


Figure 9.15. Sailor's leather shoe. NHC photo by Claire Peachey.



Figure 9.16. Ceramic base sherd (Hunhou 99-074). NHC photo by Claire Peachey.

Figure 9.17. Lead pencil (Hunhou 99-076). NHC photo by Claire Peachey.



Figure 9.18. Copper-alloy socket (Hunhou 99-067). NHC photo by Claire Peachey.

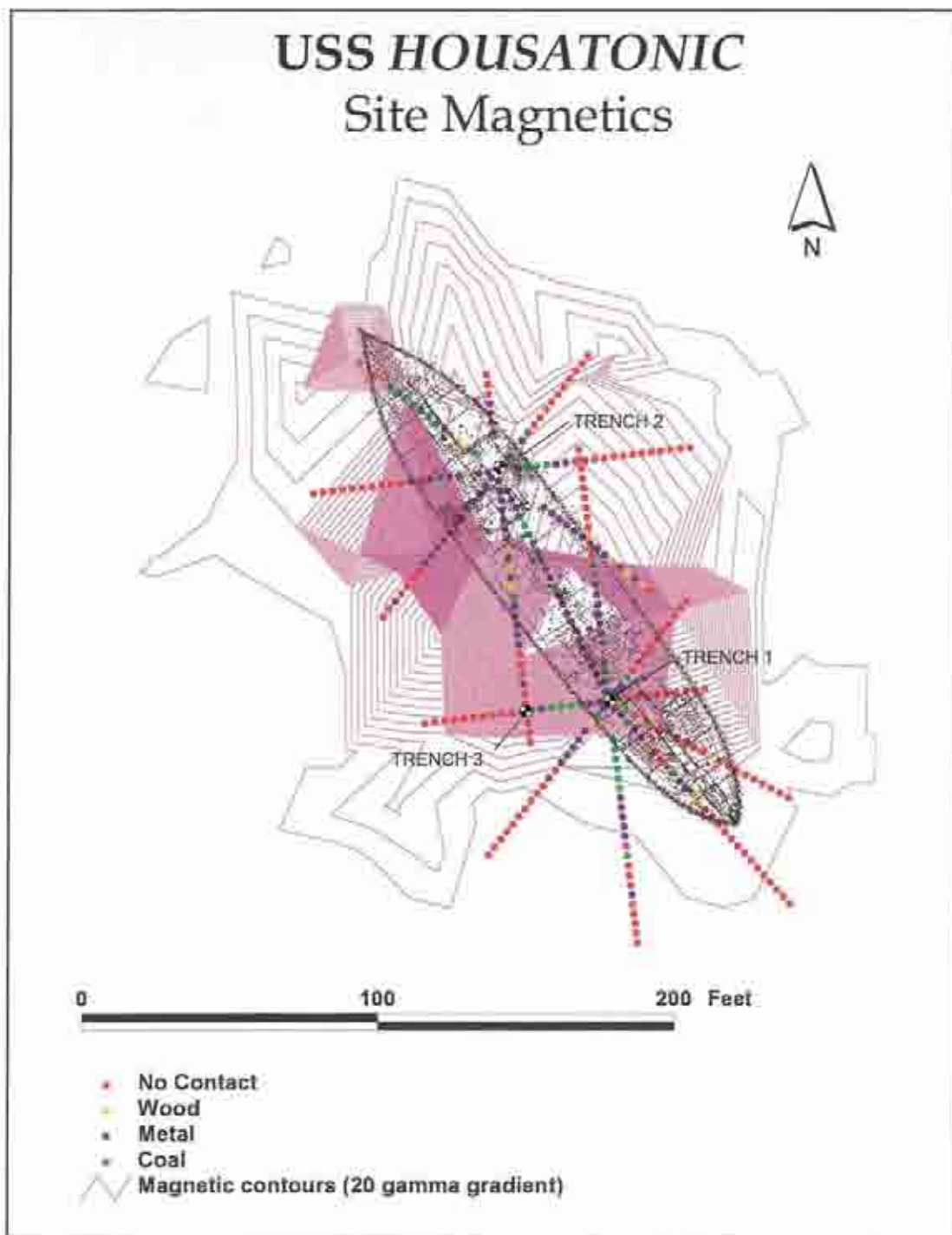


Figure 9.19. *Housatonic* and site magnetics.

boilers that had been disarticulated by explosives and affected the remaining hull structure, as examined in detail above. The materials responsible for the lobes of the main magnetic anomaly on the wreck's port side (Figure 9.20) were not ground-truthed to determine whether they were parts of disarticulated boilers, but this remains the most likely interpretation of the magnetic contours. Trench 3's location lies outside the inferred area of the original hull, but hull structure located there may be a piece of *Housatonic's* side moved by dragging or, as discussed above, it may be a section of the stern that was displaced by the original attack in 1864, by dragging or by both. Examination of the outboard edge of copper sheathing located in Trench 3 by touch (Figure 5.6) did not reveal torn or sharp edges. Lack of torn edges combined with the relatively straight edge of the sheathing indicates a probable sheathing seam or more likely the original upper edge of the copper sheathing line (Figure 9.3). If this inference is correct, then this outboard edge of the copper sheathing in Trench 3 represents the probable extent of the timbers remaining in 1870 when Captain Ludlow noted they were eaten by worms down to the copper line (Miscellaneous Wrecks, 1871–1888, RG 77, file #1125, National Archives, Southeast Region).

Copper covered the entire bottom of *Housatonic*, past the turn of the bilge to above the waterline. Typically, as upright wooden shipwrecks decay, decking is displaced, deck beams separate from hull sides, hull sides break at the turn of the bilge and fall flat. In Trench 3, wooden timbers overlay copper sheathing, which is consistent with the hull decay processes outlined above.

Alternately, this test excavation may have found an edge of the hull bottom, and the hull side may have been dragged away or is missing—though in this case, the edge of the copper sheathing should be jagged and torn. Pipes observed in Trench 3 may be parts of the

steam or water system or, alternately may be articulated or disarticulated portions of one of the boilers (Figure 2.6). As mentioned above, an additional test trench in the port stern area could provide concrete data to conclusively address the nature of these either displaced or dragged materials.

Artifacts found in Trench 3 were primarily related to *Housatonic's* structure with the exception of a fishing weight (Hunhou 99-082) and a small brass chain that was probably a sword carrier (Figure 9.20). The sword carrier would have been part of an officer's uniform, and its position, close to the stern, corresponds to cabins for Captain Pickering and the other ship's officers, all of whom would have quarters in this area (Figures 9.1 and 9.10).

Scouring and Settling

In December 1861 and January 1862, in an effort to close Charleston Harbor to Confederate shipping, Union forces under Admiral DuPont sank 30 ships of the two "Stone Fleets," in the Main Ship Channel and Maffit's Channel. Historical documents record the Stone Fleets successfully blocked entrances to Charleston Harbor temporarily, but the combined forces of scouring, redirected current flow and disintegration of the ship's structure rendered them ultimately ineffectual. Tidal and longshore currents, periodically exacerbated by storms, scoured around the sunken ships and caused them to settle into the soft sand of the ebb tidal delta. Tidal current cycles wore new channels into the sand around the fleet opening other means of access to the harbor. Concurrently, as the wood of the ships rotted or was eaten away, the effectiveness of the hulks as obstructions diminished, ultimately becoming useless. The fate of the Stone Fleets foreshadowed that of all elements of the Engagement Site—*Housatonic*, *Hunley* and the Third Anomaly.



Figure 9.20. Officer's sword carrier (Hunhou 99-090). NHC photo by Claire Peachey.

General Principles

Both artificial reef specialist Mel Bell (Appendix B) and Geologist Mark Hansen (Appendix E) independently characterize scouring and settling dynamics that explain part of the burial processes of both the Stone Fleets and archeological materials of the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site. Geological data derived from an analysis of vibracore stratigraphy, sedimentological analysis and geophysical characterization of vibracore subsamples support their conclusions (Chapter 8).

Specific dynamics of *Hunley* and *Housatonic* may not be precisely determined, but the general process can be understood as the interaction between several factors including: current speed and duration, wreck height and length, angle of contact between current and wreck, wreck shape and weight (density) and geophysical characteristics of surrounding sediments.

A fundamental variable in wreck scouring is current speed and duration. High velocity,

steady currents, such as those in Charleston Harbor (Chapter 8), would be expected to produce significant scour and settling. The Hjulstrom diagram presented in Chapter 8 (Figure 8.18) shows effects of current speeds on different sized sediment particles. Several issues illustrated in the Hjulstrom diagram are important for an understanding of scouring and settling processes: 1) As current speed increases, so too does the size of sediment it is able to move; 2) Larger particles can only be picked up by higher velocity currents, but settle out relatively rapidly as current speed diminishes; 3) Small clay and silt particles also need high speed currents to be picked up, but once suspended stay in suspension for a long time; and 4) Particles remain suspended and are transported in slower current speeds than it takes to pick them up initially.

Currents in the region of the Engagement Site are not constant but vary in speed and direction over time. As currents strike obstructions from different angles, they deposit

and scour away sediments in different areas around it. In addition, short periods of rapid current flow can have a disproportionate impact on scour and settling processes. Bell's analysis (Appendix B) states that periodic storm effects contribute to rapid and extensive settling in newly emplaced artificial reef structures in Charleston Harbor. Consequently, storm effects must be considered when discussing settling of *Hunley*, *Housatonic* and the Third Anomaly (Chapter 8).

Bernoulli's equation states that with an incompressible liquid, all other factors being equal, when pressure increases, speed decreases and when pressure decreases, speed increases (Figure 9.21). As currents carrying sediments encounter an obstruction, pressure increases, speed decreases and large particles settle out—a process that explains the lenses of shell hash found around *Housatonic* (Chapter 4). After moving over or around an obstruction, pressure

decreases, speed increases and sediment particles are picked up. Because it takes more current velocity to pick up a particle than it does to transport it, large particles on the down current side of an obstruction are not resuspended and transported away. However, smaller particles on the down current side of an obstruction are picked up and moved. The resulting scour hole this creates leads to settling and eventual partial or total burial of an object.

Because sediment transport around an obstruction is related to current speeds (which are, in turn, related to hydrodynamic pressure), wreck scour and settling correlates with the displaced current. Wreck shape, therefore, is also an important variable to consider when looking at scour. A relatively hydrodynamic wreck sitting on the bottom creates less dramatic pressure changes and should scour less than one that obstructs more current. As a wreck scours and settles, the cross-sectional area interfering

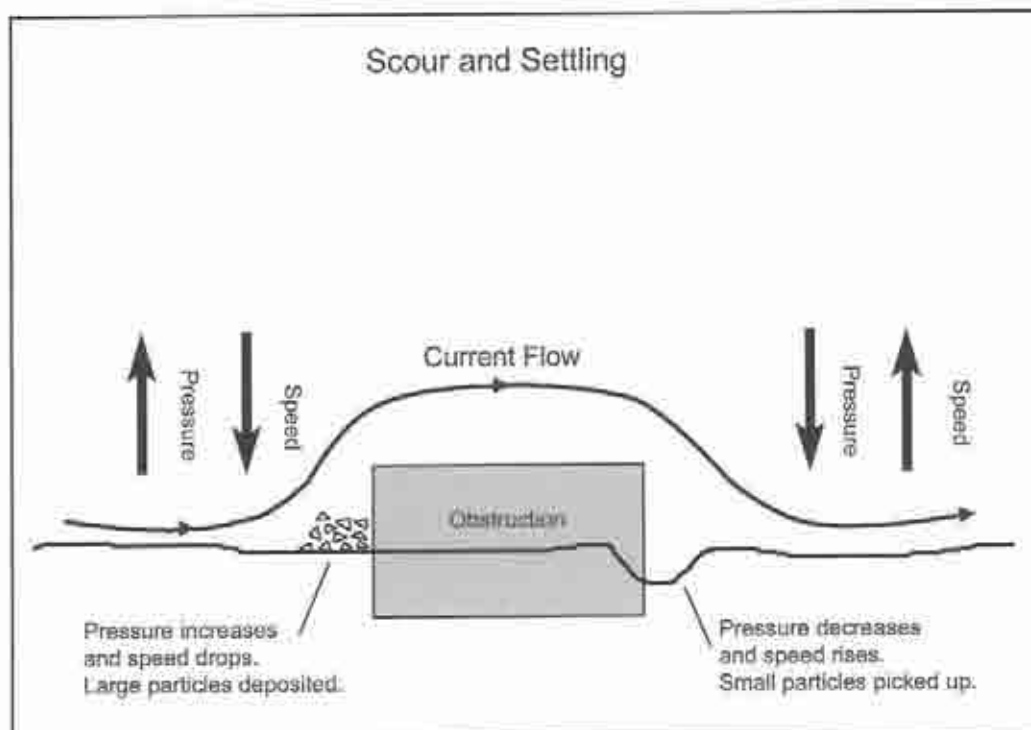


Figure 9.21. Sediment flow and deposition around an obstruction.

with current flow decreases and, other variables remaining constant, it probably settles at a slower rate and eventually halts as the structure is buried. Therefore, it follows that taller wrecks will settle deeper than shorter wrecks. Added to this equation must be some acknowledgement of the influence of the wreck's length, which changes the amount of area presented to currents, the amount of water displaced, and therefore, the degree of scour. The angle of contact between currents and the wreck also affects the amount of water that is redirected as well as pressure, and this also affects scour. Wrecks oriented perpendicularly to current flow scour fastest, and wrecks oriented with a very narrow cross section to prevailing currents scour less.

The density of a wreck also influences the degree to which it settles. As a wreck settles, skin friction between the wreck and surrounding sediment increases. A heavy wreck, such as one of the Stone Fleet ships, would tend to overcome skin friction caused by surrounding sediments and settle deeper than a wreck such as the Third Anomaly that is both light weight and has a large surface area, so it is proportionally more affected by friction with the surrounding sediments. The interrelationship of object density, skin friction and the geotechnical characteristics of surrounding sediments provides a partial explanation for the observed variations in depths of the Engagement Site features.

A final variable to consider is the geophysical characteristics of the bottom sediments. Looking again at the Hjulstrom diagram, we can see that in loose, sandy sediment, particles are more easily picked up and transported, and a wreck should scour and settle much faster on a bottom of this sort than in more densely compacted silt or clay strata. If the sediments are layered and the layers have different physical characteristics, then that also affects the rate and depth that the wreck settles.

If a relatively dense and cohesive layer overlays a relatively loose and unconsolidated layer, a wreck would be expected to scour slowly until it settles through the dense layer, but then settle more quickly as it moved into the looser and more unconsolidated layer. Conversely, if a loose, unconsolidated layer overlies a denser, more consolidated layer, as is more often the case, then a wreck should settle relatively quickly until it reaches the denser lower layer where it will slow or stop settling.

Housatonic Scour

In light of the discussion above, an examination of the sedimentary data derived from the US Geological Service (USGS) vibracoring operations including sediment dating (Appendix F), sedimentation dynamics (Appendix E) and the Soils Consultants, Inc. geotechnical analysis (Appendix D; Chapter 8) helps explain site formation processes for the USS *Housatonic* wreck. Charleston Harbor's ebb-tidal delta, composed primarily of fine to very fine sands, overlies a stratum of more densely compacted Pleistocene clay. Based upon ^{210}Pb dating data and an analysis of sub-bottom profiler data (Appendix F; Chapter 8) in the area of both *Hunley* and *Housatonic*, this sandy, relatively unconsolidated layer above the clay layer was approximately 2–3 ft. (.6–.9) thick at the time of both vessels' loss. Muddy, shelly sediments starting at approximately 4 ft. (1.2 m) below the modern bottom are Holocene and mark the probable level prior to jetty construction (Figure 9.22). This was the approximate position of the bottom *Housatonic* landed on when it sank on February 17, 1864. By November 26, 1864, 10 months later, Lieutenant Churchill's salvage divers reported *Housatonic* had settled in an upright position and had scoured into the sand about 5 ft. (1.5 m) forming a bank of mud and sand around it

(ORN ser. 1:15:334). At the time of these diver observations, *Housatonic's* keel was just penetrating the Pleistocene clay layer. This clay layer is clearly discernible in vibracore HOUS 3 (Figure 9.22), the vibracore taken closest to the water tanks documented in Trench 2. On June 24, 1999, 135 years after sinking, documentation of these water tanks showed them to be 4 ft. (1.2 m) below the present seabed. Looking at a cross section of *Housatonic's* sister ship, USS *Ossipee*, allows us to infer the location of the keel today as having scoured about 1½ to 3½ ft. (.5–1.1 m) into the Pleistocene clay layer.

After sinking, *Housatonic* landed on a bottom of relatively unconsolidated Holocene muddy, shelly sediment and scoured quickly through to the firmer Pleistocene layers below. Though no geotechnical tests were done on the *Housatonic* vibracores, the same strata were located on the *Hunley* site and were analyzed by Soil Consultants, Inc. on vibracores HUSB1A, HUPS2A and HUPB 1A. Analysis indicated this muddy, shelly layer has an average cohesive strength of 414 psi (Chapter 8; Appendix D). The Pleistocene layer that the *Housatonic* wreck scoured down to sometime before Churchill's examination 10 months later has a measured cohesive strength of 1,075 psi—an increase of 259 percent and this, combined with the reduced area of the hull diverting current flow accounts for the much slower rate of scouring and settling into the Pleistocene clay layer. The rate of *Housatonic's* settling decreased dramatically once the bottom of the hull hit the firmer Pleistocene layer, and the wreck probably slowed even further after its cross-sectional area was reduced by Maillefert's salvage activities in 1873–1874. In February 1909, William Vierden dynamited and dragged the wreck leveling it to the seabed. At this point, the wreck no longer impeded current flow and scouring and settling almost certainly ceased.

In 1868, Charleston was hit by a massive earthquake. The earthquake fluidized

sedimentary strata onshore and numerous buildings subsided and collapsed. No evidence exists as to the offshore effects of the quake, but it may have similarly fluidized the Pleistocene strata underlying *Housatonic's* hull. If this were the case, the wreck (and other archeological materials in the Engagement Site) may have experienced a sudden subsidence as the Pleistocene clay layer temporarily lost its bearing strength.

Sedimentation in the area of the *Housatonic* wreck accelerated following completion of the Charleston Jetties in 1895. Geologist Mark Hansen's analysis of sediment transport patterns in the area of *Hunley* and *Housatonic* (Chapter 8; Appendix E) explains why the shallowest portion of the wreck documented archeologically, the water tanks in Trench 2, were buried 4 ft. (1.2 m) below the bottom and why the initial excavations in Trench 1 were 6 ft. (1.8 m) below the present (Chapter 4). Jetty construction diverted the dominant southwestwards longshore sediment transport further offshore. As currents moved into deeper waters offshore, they slowed and dropped their sediment load. This alteration of currents by the jetties resulted in net sediment accretion of approximately 4 ft. (1.2 m) in the area of *Housatonic* and 3 ft. (.9 m) in the area of *Hunley* (Figure 9.23). The water tanks in Trench 2, which are the shallowest features documented during fieldwork, would have been approximately level with the seafloor following Vierden's 1906 dragging, but were subsequently buried 4 ft. (1.2 m) deep by the new sedimentation regime created by the jetties.

²¹⁰Pb

Analysis of the ²¹⁰Pb data (Appendix F) for vibracore HOUS 3 establishes a sedimentary accretion chronology above *Housatonic*. Sediment accumulation was episodic, sometimes proceeding at a faster rate

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...the tenth is the fact that the ...
 ...the eleventh is the fact that the ...
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USS *Housatonic* Site Stratigraphy

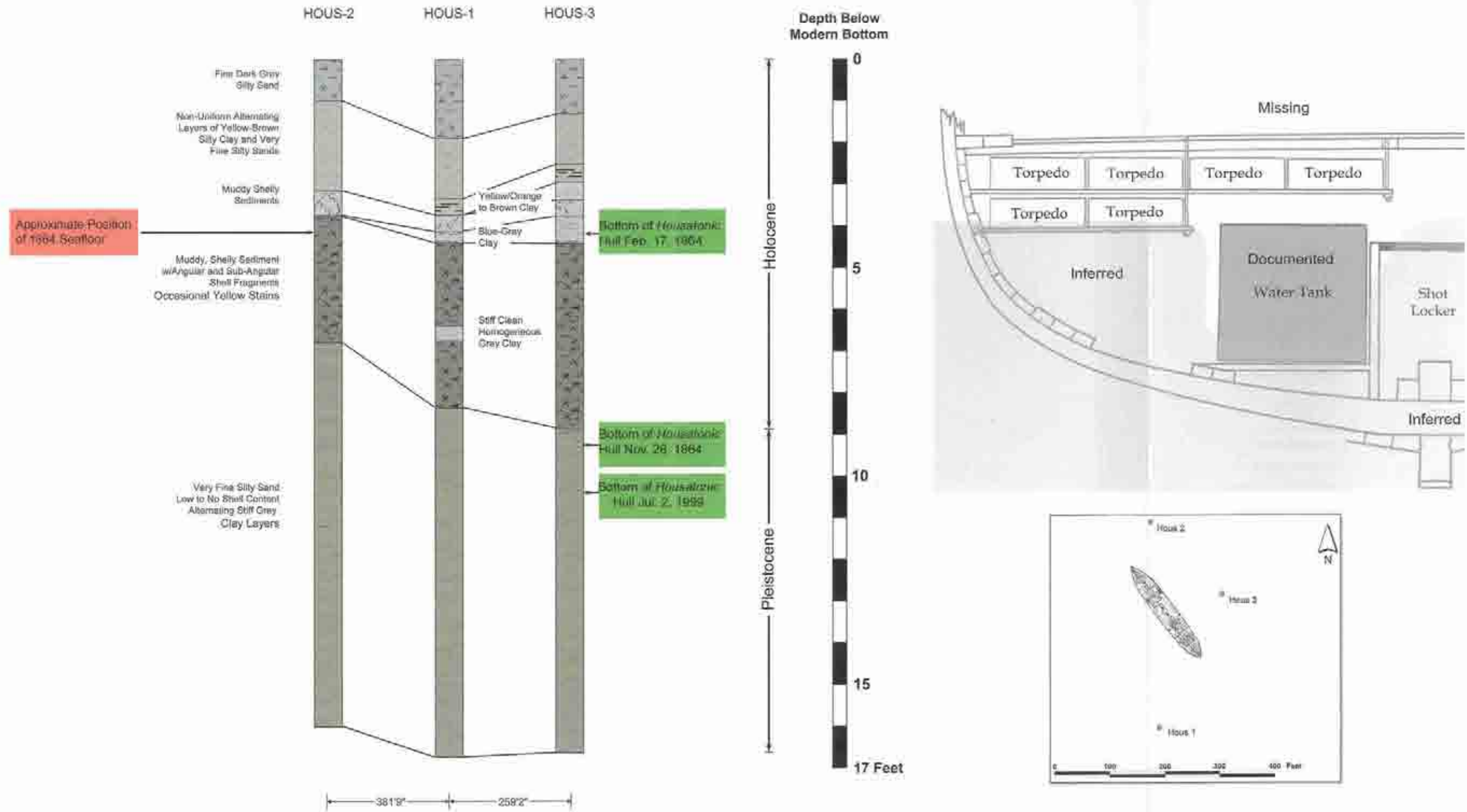


Figure 9.22. *Housatonic* Site Stratigraphy

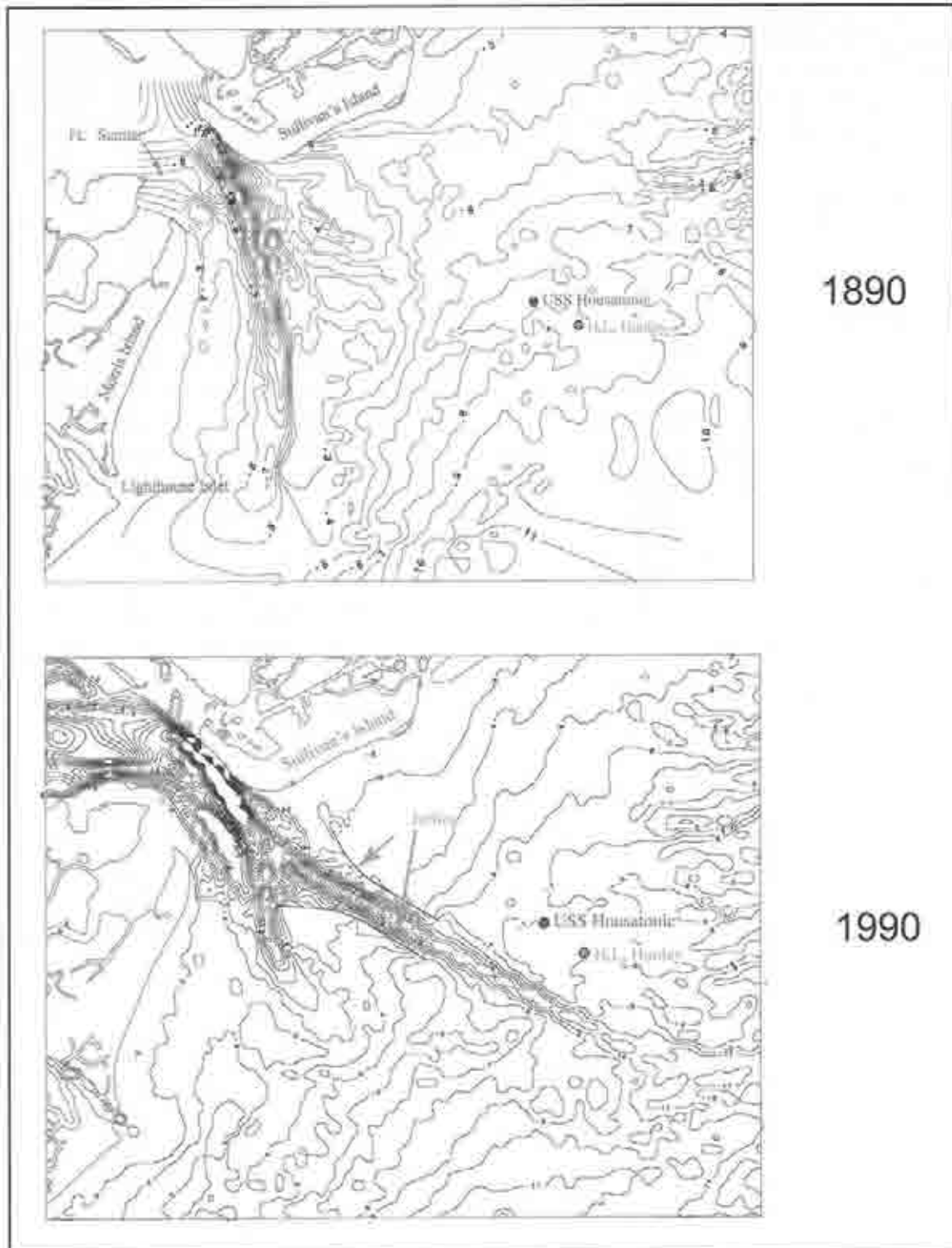


Figure 9.23. Comparative bathymetry 1890–1990. Sea level has risen on the order of 2 ft. since 1864 and depth values are not corrected (Chapter 6). All depths are in meters.

than at other times, which is probably due to storm activity (Chapter 8), but these burial episodes were not interrupted by periods of erosion. Sediment accumulation over the site was cumulative, and the ^{210}Pb decay pattern does not show a double curve (which would be diagnostic of episodic sediment erosion) over *Housatonic* (Marci Marot, personal communication 2000). Increased radioactivity in the HOUS 3 core at the 160–200 cm depth is interpreted as the result of intrusion of mineral enriched sands with a high uranium content, and not a turnover in sedimentary strata. In short, ^{210}Pb data generated from the HOUS 3 vibracore agree with data generated during the 1996 examination of *H.L. Hunley* (Murphy et al. 1998:117), and together they show that once longshore sediments covered them after jetty construction, both sites remained buried until the present day.

^{210}Pb data show an aggregate sedimentation rate of 0.35 ± 0.11 in./year (.9–1.2 cm) on the site of *Housatonic*, which translates into a projected accumulation of 3.94 ft. (1.2 m) of sediment over the wreck with ± 1.24 ft. (.37 m) (Appendix F) occurring between 1864 and 1999. This result corresponds very well with the observed depth of 4 ft. (1.2 m) to the highest measured point on the wreck, the tops of the water tanks in Trench 2, and explains why materials that were reportedly level with the seafloor in 1909 are now buried beneath mud and sand.

Site Integrity

Examination of the probe data (Figure 5.2; Figure 9.5; Appendix C; Chapter 5) indicates that, despite a massive explosion caused by *Hunley's* attack and multiple episodes of salvage and clearance, the *Housatonic* wreck has considerable integrity, with several feet of vertical relief and contiguous structure spanning at least 7,300 sq. ft. (678.1 sq m).

Judging from the depth below the sediment of the water tanks in Trench 2, there is approximately 10 ft. (3 m) or roughly 30 percent of the original *Housatonic* hull remaining (Figure 9.24). The hull located in situ is from below the waterline, the hull structure above was removed by decay, salvage and wreck-clearing activities. Recovery of well-preserved organic artifacts, such as shoes and wood, show that the wreck was not cleared of portable artifacts by either salvage or subsequent, undocumented human visits to the site. Magnetic data do tend to indicate dispersal of unknown metallic elements from the wreck, primarily on the port side, but this does not seem to have affected other parts of the wreck, such as the water tanks in Trench 2, that are apparently still articulated with the rest of the wreck. Most likely this metal material off the port side is elements of hull structure and ship's machinery dispersed by postdepositional salvage and leveling activities.

THIRD ANOMALY: ANALYSIS

THIRD ANOMALY HISTORY

The Third Anomaly is almost certainly a buoy that marked the *Housatonic* wreck as a navigation hazard. The 1870 Coast Survey chart of Charleston Harbor shows a buoy marking the *Housatonic* wreck. When this chart is georectified to bring it into accordance with the 1996 and 1999 survey data, the 1870 buoy position is 430 ft. (131 m) from the present location of the Third Anomaly and 915 ft. (278 m) from the present location of *Housatonic*. Following lowering of the wreck to the silt line by William Vierden in 1909, there was no reason to keep the buoy in place, and, since it may have been almost 40 years old at the time, there may have been no reason to reuse it somewhere else. It may have been sunk in place or close to where it was originally anchored. Another possibility,

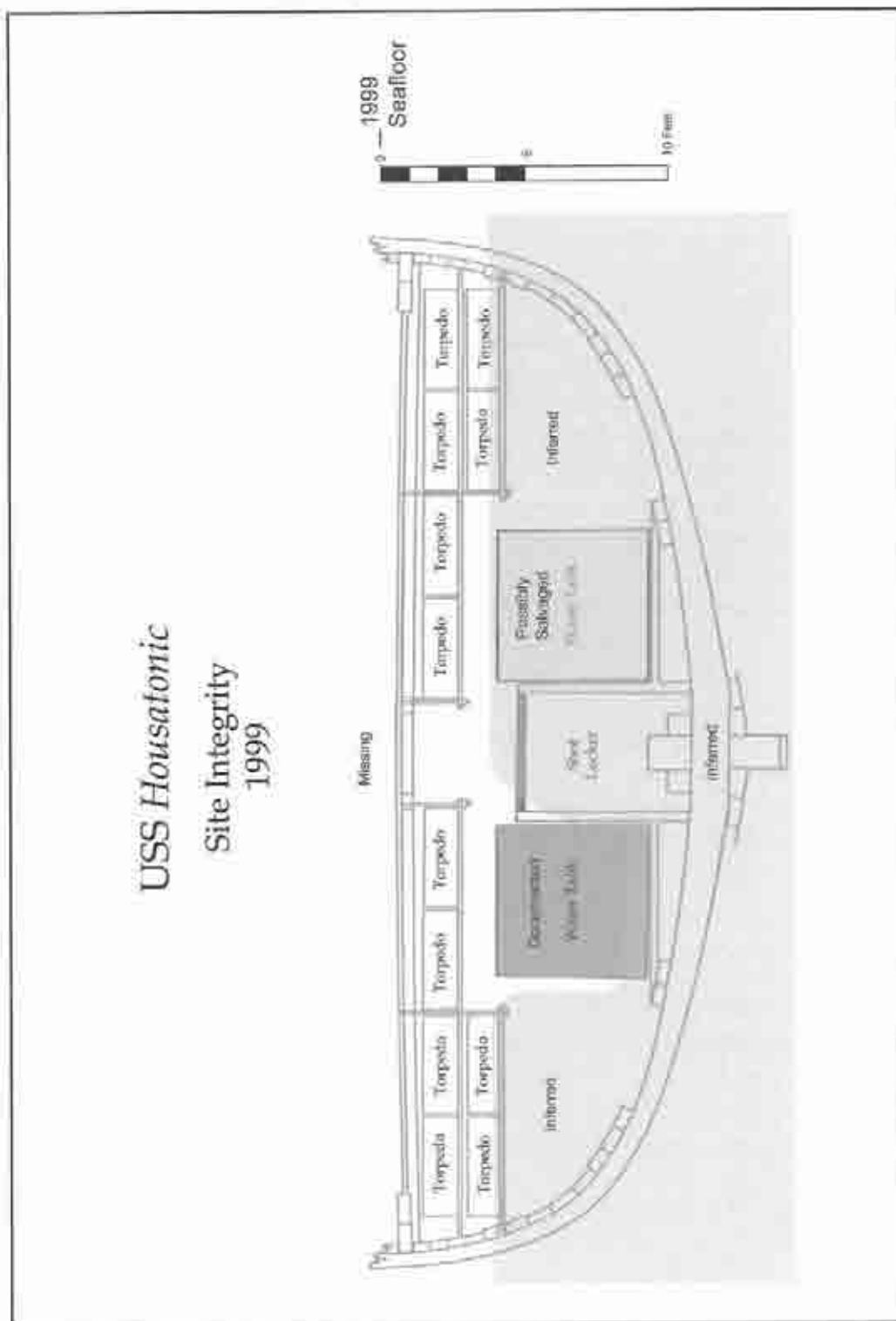


Figure 9.24. *Housatonic* cross section through forward hold (Trench 2) looking aft.

that the buoy had already sunk by 1909, cannot be entirely discounted.

THIRD ANOMALY ARCHEOLOGY

The two artifacts recovered from the Third Anomaly, the wire and polypropylene rope (Hunhou 99-001), and the weight (Figure 9.25) indicate the buoy has been visited by divers at some point after 1959. Commander David Whall (personal communication 1999), a retired Mobile Underwater Diving and Salvage Unit officer for the United States Navy, noted that the materials used to construct the weight may indicate that whoever made it was concerned that it was nonmagnetic. Navy Explosive Ordnance Disposal (EOD) personnel frequently construct and use nonmagnetic weights as a normal part of their duties. Until 1968, the US Navy's EOD Mobile Unit Two was stationed in Charleston, and, though there is no conclusive evidence of EOD personnel diving on the Third Anomaly (presumably as part of training), it is presented here as a possibility.

THIRD ANOMALY SITE FORMATION PROCESSES

Scouring and Settling

Though the time at which the Third Anomaly settled on the bottom is unknown, the scour and settling dynamics that affected *Housatonic* produced similar results on the buoy. The diameter of the buoy's larger end was measured as 8 ft. 7 in. (2.63 m) during field operations, and it protruded off the bottom approximately 10 in. (.25 m) (Figure 5.7 and Chapter 4). Based on analysis of the two closest USGS vibracores (HOUS 1, 510 ft. [155 m] away; HOUS 3, 450 ft. [137 m] away), this object, presumably a hazard buoy, lies upon the same Pleistocene clay stratum that slowed and then stopped *Housatonic's* scouring (Figure 9.26).



Figure 9.25. Copper, lead and brass dive weight (Hunhou 99-002). NHC photo by Claire Peachey.

The Third Anomaly appears to be a hollow iron structure, its light weight relative to its large surface area probably slowed the rate of settling due to increased skin friction with sediments as it scoured into the harbor floor. This skin friction created an equilibrium between the supporting buoyancy of the surrounding sediments and the downward impetus of scour. The relatively low density of the object prevented it from scouring into the firmer Pleistocene clay layer, and it stopped settling when, or possibly before, the bottom of the object contacted the firmer lower stratum. Because the object was large enough in diameter to protrude through both the unconsolidated sediments of the Civil War harbor bottom and strata subsequently deposited by rediverted longshore sediment transport, upper portions of it have remained exposed.

Biological Colonization

The Third Anomaly buoy has recently acted as a solid substrate for worm colonies, which accounts for the wormrock recovered during field operations (Chapter 5). Biologist Bob Martore and artificial reef specialist Mel Bell examined the recovered wormrock and described its biological family and preferred environment (Appendix B). According to Martore, wormrock is the remains of a marine worm colony from the family *Sabelliidae*, which is found in the near-shore and intertidal areas out to substantial depths in this area. *Sabelliidae* colonies live in high-energy marine environments where turbulence produces a large sediment load in the water that is used for tube building, food and larvae dispersal. Colonies grow rapidly and can reach several feet across and up to 2 ft. (.6 m) thick in two to three years. Following the death of the worms in a colony, it begins to deteriorate. The rate of deterioration for the dead colonies is not known, but is probably primarily dependent upon wave and current energy as well as water and sediment chemistry that breaks down the protein used by the worms to create their tubes.

What is interesting about wormrock colonies for a discussion of settling and scour is that they indicate that surfaces, such as the upper parts of the Third Anomaly that are now buried were exposed relatively recently. A detailed examination of the rate at which the wormrock colonies degrade in the environment due to breakdown of their constituent proteins could provide an additional line of evidence for dating burial events and sedimentation rates in environments similar to Charleston Harbor. In absence of these data, it appears that the many individual wormrock colonies attached to the upper surface of the Third Anomaly indicate a recent and rapid burial event, perhaps resulting

from the rapid and extensive transport of sediments offshore as a result of Hurricane Hugo in 1989 (Chapter 8). Bell and Martore's analysis, based upon lack of discoloration typical of extended burial, is that the wormrock colony was covered with sediment relatively recently. Martore (personal communication 2000) reports that exposed colonies of wormrock degrade in a matter of months, largely as a result of current action, but they may last longer if buried. That the wormrock colony observed attached to the Third Anomaly grew around a length of polypropylene rope means that the colony must have grown sometime after about 1958 when polypropylene became widespread in the United States (William Haas, personal communication 2001).

FOURTH ANOMALY: ANALYSIS

FOURTH ANOMALY HISTORY

As described in Chapter 5, the Fourth Anomaly is an Admiralty type anchor buried about 5 ft. (1.5 m) below the silt line. Admiralty type anchors were developed under Royal Navy Admiral Sir William Parker and first used in the British Navy in 1841 (Curryer 1999:83–84). The design spread quickly, and variants are still in use.

Anchors for various ships are specified by weight, and this can be calculated using the formula: anchor weight in hundredweight (cwt.) (or units of 110 lbs.) = overall length³ x .0114 (Cyclopedia of Useful Arts 1854:np). According to this formula, the Fourth Anomaly anchor weighs 1.43 cwt. or 157 lbs. Rounding up to 1.5 cwt., according to the *Standard Classification of American Vessels* (American Shipmasters' Association 1879:xxx), this is the minimum size for a 75-ton vessel's stream anchor or a kedge anchor for a vessel of 175 tons—*Housatonic* was built at 1,934 tons

(Bennett 1896; Appendix B). Therefore, *Housatonic* would not have relied on an anchor of this size as a main or secondary anchor.

Testimony at the Court of Inquiry that followed *Housatonic*'s sinking indicated that the anchor was slipped as the ship backed to avoid the *Hunley* attack (Bak 1999:163). Slipping the anchor was much faster than retrieving it and allowed Union ships a reasonable chance of intercepting incoming and outgoing blockade runners. To facilitate recovery, the anchor chain was tied off with a buoy. According to court testimony, this buoy was cut loose from *Housatonic* by George Kelly, one of the ship's coopers (Bak 1999:169). The buoyed anchor would probably have been one of the first items recovered as salvage by the *Canadiagua*.

FOURTH ANOMALY ARCHEOLOGY

Early models of the Admiralty anchor had a wooden stock, and it is likely that the Fourth Anomaly anchor had a wooden stock that is now missing due to decay. The depth at which the anchor is buried (5 ft. [1.5 m]) as well as the probability of a wooden stock makes it earlier or contemporaneous with both *Hunley* and *Housatonic*.

The open-link anchor chain associated with the Fourth Anomaly anchor was measured at 1½ in. (3.8 cm) in diameter. The *Standard Classification of American Vessels* (American Shipmasters' Association 1879:xxx) states that anchor chain should be stud-link. A 1½-in. (3.8 cm) diameter stud-link chain is the minimum size for a vessel of 600 tons. Because open-link anchor chain is weaker than stud-link chain, it is quite possible that larger diameter chain was used for a smaller vessel. Overall, the combination of large diameter, open-link chain and a relatively small anchor trends towards a rather haphazard or opportunistic approach to

the procurement of ground tackle. This is not consistent with regular military practice and more likely indicates a local fishing or merchant anchor. A less likely possibility is that this anchor may have been associated with *Housatonic* salvage activities.

The back bearing taken on the shaft of the Fourth Anomaly anchor pointed at 188° true. This points the shank somewhere between the Third Anomaly and the *Housatonic* wreck, but not directly at either one (Figure 4.1).

In summary, it is unlikely that the anchor producing the Fourth Anomaly came from *Housatonic*, and association with the site is also unlikely, though possible. This conclusion is based upon the anchor's size, type of chain, probability that the original *Housatonic* anchor was salvaged, and the orientation of the shank relative to the wreck. While possibly contemporaneous, the anchor seems more likely to have come from a small, perhaps local, merchant or fishing vessel.

HUNLEY: ANALYSIS

HUNLEY HISTORY

While *H.L. Hunley*'s attack on the night of February 17, 1864, was fatal to *Housatonic*, it was, apparently, not immediately fatal to the submarine. According to Landsman Robert Flemming who was clinging to the rigging awaiting rescue by USS *Canadiagua*, *Hunley*'s signal for success, the blue light, was shining in the water approximately 50 minutes after the attack four ship-lengths away from *Housatonic* and off the starboard quarter (Bak 1999:165). This sighting was independently confirmed by Confederate Lieutenant Colonel Danzler manning battery Marshall at Breach Inlet in his report to General Beauregard two days later (ORN ser. 1:15:335).

HUNLEY ARCHEOLOGY

Flemming's observed position of *Hunley* corresponds with the archeologically documented position of the submarine—four ship-lengths, or approximately 820 ft. (250 m), compares very well with the 998 ft. (304 m) measured from the Trench 2 datum to the submarine's bow where it was found buried in sediment in 1995. Flemming's position of the submarine as "off the starboard quarter" also agrees very well with *Hunley*'s location compared to the historically attested and archeologically documented orientation of *Housatonic*.

The historical evidence shows that *Hunley*'s crew survived the attack and were coherent enough following the explosion that destroyed *Housatonic* to signal their success to shore. Judging from *Hunley*'s archeologically documented position as compared to that reported by Flemming, it seems plausible that shining the blue light was the last, or close to the last, thing that the submarine's crew did prior to sinking.

HUNLEY SITE FORMATION PROCESSES

Scouring and Settling

Hunley settled and scoured in the same way that *Housatonic* and the Third Anomaly did, though in this case, the differences in sedimentation rate due to a location further offshore resulted in overall shallower settling and burial. *Hunley* lies buried under approximately 3 ft. (.9 m) of sediment, and this burial depth, combined with the measured dimensions of the hull in situ, place the bottom of the keel approximately 1 ft. (.3 m) into the firm layer of Pleistocene clay (Figure 9.27). As with *Housatonic*, on the night of sinking, *Hunley* settled onto the rather loose, unconsolidated layer of sand that was about 2 ft. (.6 m) thick,

overlying the Pleistocene clay layer. Judging from the historically attested rate of scour and settling for *Housatonic*, *Hunley* settled rapidly through the sand layer until it hit the firmer clay layer beneath. Held up by the firmer clay layer, the scouring and settling eventually slowed and stopped.

Scientific analyses done as part of the 1996 *Hunley* assessment (Murphy et al. 1998:99) suggested that the upper portions of the submarine were buried approximately 20–25 years after sinking. These conclusions are consistent with the scouring and settling sequence outlined above as well as historical changes in Charleston sedimentation brought about by the construction of the jetties.

Following scouring to the Pleistocene clay layer, the upper portions of the submarine remained exposed and served as a substrate for colonization by oysters and coral (Murphy 1998; Appendix C). After a period of exposure, the upper portions of *Hunley* remaining above the sediment line, were buried by longshore sediments diverted by the Charleston jetties. Eventually, approximately 3 ft. (.9 m) of diverted sediments buried the previously exposed upper surfaces of the submarine, and the entire wreck was buried without evidence of subsequent exposure until its rediscovery in 1995.

²¹⁰Pb

As with the *Housatonic* ²¹⁰Pb dating, analysis of the ²¹⁰Pb data for vibracore HUSB1B (Appendix F) delineates a chronology for sedimentary accretion occurring over *Hunley* after its loss in 1864. Sediment accumulation over *Hunley* proceeded uninterrupted at variable rates (probably due to storm activity). As with *Housatonic* and in agreement with the 1996 *Hunley* assessment, this accumulation was not interspersed with periods of erosion. The ²¹⁰Pb curve for HUSB1B shows a consistent decay pattern down to approximately the 80 cm depth,

H.L. Hunley Site Stratigraphy

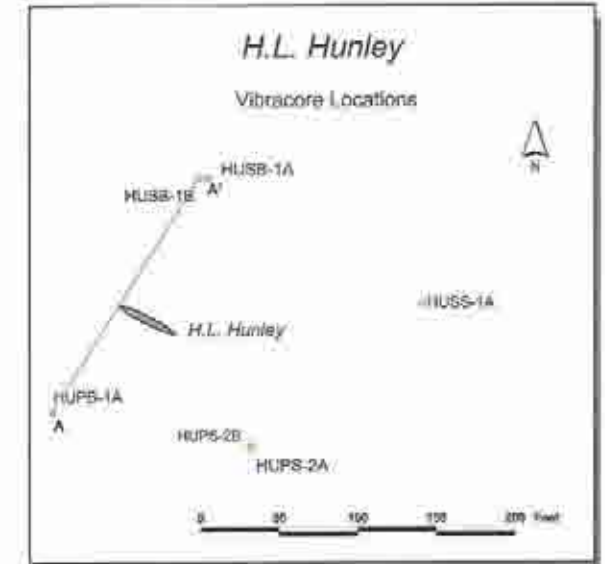
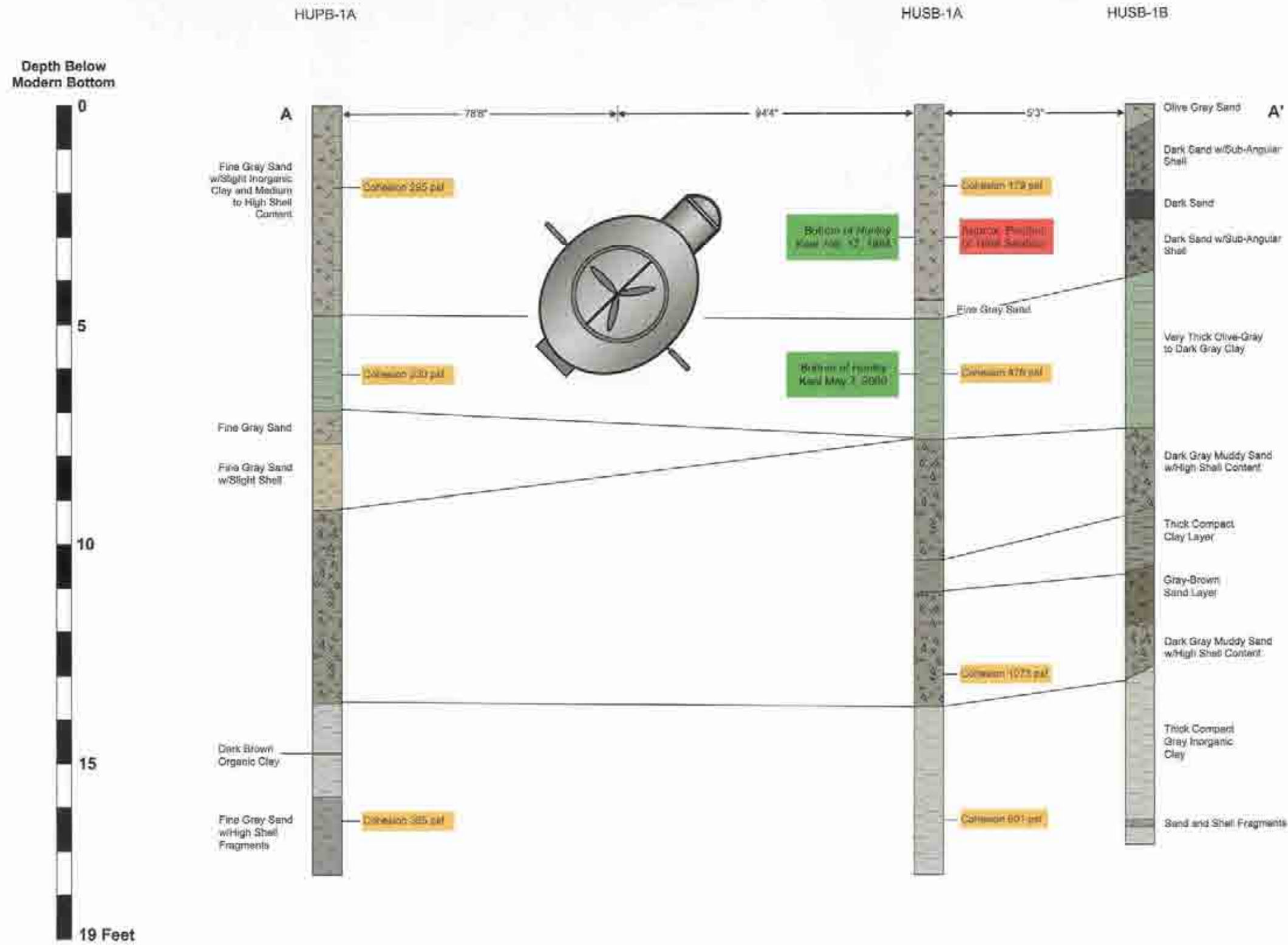


Figure 9.27. H.L. Hunley Site Stratigraphy

which indicates sediments below this level are older than six isotope half-lives, or approximately 120 years. There is no indication from the ^{210}Pb data from the HUSB1B vibracore that once *Hunley* was buried, it was ever subsequently uncovered. Had the wreck been uncovered, the ^{210}Pb would have been refreshed and produced younger dates with an inconsistent decay curve.

Sedimentation rate for the *Hunley* core is 0.29 (7.4 mm) \pm 0.10 (2.5 mm) in./year, which indicates a net burial of 3.26 ft. (1 m) \pm 1.13 ft. (.34 m) between 1864 and 1999. This agrees well with the burial depth of approximately 3 ft. when *Hunley* was excavated as part of the 1996 assessment.

Aggregate sedimentation rates of 0.35 (8.8 mm) \pm 0.11 (2.8 mm) in./year on the *Housatonic* site and 0.29 (7.4 mm) \pm 0.10 (2.5 mm) in./year on the *Hunley* site (Appendix F) account for the different burial depths observed for each site. This 27 percent difference in sedimentation rate is probably due to the fact that the *Housatonic* wreck sits approximately 1,000 ft. (1 km) closer to shore than *Hunley* and, consequently, receives more sediment load from diverted longshore currents. *Housatonic* is buried an observed minimum of 4 ft. (1.2 m) below the mud line, and *Hunley* is buried about 3 ft. (.9 m) deep—a difference of 25 percent, which accords well with the difference in the estimated burial rates for the two sites as indicated by ^{210}Pb data.

SEDIMENT STRENGTH

Sediments around *Hunley* were analyzed to determine whether it would be possible to recover the submarine entirely encased in its surrounding matrix. This was one of the recommendations from the 1996 *H.L. Hunley Assessment* (Murphy, Lenihan and Amer 1998:120). Analysis done by Soil Consultants, Inc. on the sediments' geophysical

characteristics around and under *H.L. Hunley* (Appendix D), indicates these sediments did not have sufficient strength to support the submarine throughout recovery and transportation. While stable in a static environment, cohesion and shear stress analyses showed there was an unacceptable possibility that the sedimentary matrix would fluidize under the dynamic stresses experienced as an unavoidable part of recovery operations. If this happened, the submarine would settle in the matrix and possibly be damaged. The potential fluidization of sediment exposed to dynamic forces may correlate with the possibility that sediment fluidized as a result of the Charleston earthquake in 1886, leading to settling of the submarine.

These data allowed engineers at Oceanering Advanced Technologies, the company that eventually developed the successful plan to recover the submarine, to discard this option and concentrate on more promising alternatives. Eventually, a plan was formulated to excavate the submarine in situ and raise it with a system of slings, pads and an overhead frame. *H.L. Hunley* was recovered intact and undamaged on August 8, 2000.

SUMMARY

Housatonic moved from an unremarkable 2nd rate sloop-of-war to the unwitting victim of the world's first successful submarine attack in a number of incrementally minute events that were devastating in culmination. First and foremost of these events was the capture of Port Royal South Carolina by Admiral DuPont on November 7, 1861. This secure anchorage on the doorstep of Charleston allowed for a close blockade of the Confederate port that increased in efficiency as more Union ships were built and added to the blockade. Without Port Royal, the blockade never could have been enforced as rigorously as it was, and General Beauregard might never have felt compelled to use *H.L.*

Hunley—a vessel that had killed 13 men prior to its final mission in 1864—to try to break the blockade in the desperate days preceding and following the Union capture of Morris Island in the fall of 1863.

Loss of USS *Keokuk* following the abortive first ironclad attack on Fort Sumter by Admiral DuPont in April 1863 was not as important to *Housatonic* as was the loss of *Keokuk*'s code book. Had the code book not been lost, then the sharp-eyed Confederate defenders of Charleston might not have been able to read about Dahlgren's preparations for the small-boat attack on the night of September 8, 1863. Had Southern forces been caught by surprise, Union losses would have been considerably smaller, and William Beebe, the officer's steward for *Housatonic*, might not have been captured. Had Beebe not been captured, he would not have sworn an oath of allegiance to the Confederacy and "...given all the information in his power regarding the squadron in Charleston" (ORN ser. 1:14:630). Had Beebe not defected and offered up valuable military intelligence to the defenders of Charleston concerning his ship and the others in the blockade, Dixon might have selected another ship (or a different place on the same ship) to attack. In short, the precise placement of *Hunley*'s charge may reflect the importance of Beebe's information to Dixon and his plans for the attack.

Parallel to developments on the Confederate side were those for the Union. Had the North not been so heavily vested in depicting ironclads as weapons that were virtually invincible, then their failure in the April 1863 attack might not have been rewritten as a command failure. Had the loss of *Keokuk* been seen as the result of armor too thin for the guns directed at it, or had Secretary of the Navy Welles kept his promise to back Admiral DuPont whatever the results of the attack, then John Dahlgren probably would have kept his job as a talented engineer

and armorer at the Washington Navy Yard, and events would have proceeded differently. Dahlgren, as a scientist and engineer, was quick to appreciate the hazards posed to the Union blockade by Confederate torpedoes, *David* and *Hunley*, and this, too, is an important part of *Housatonic*'s history.

Beauregard's insistence on the necessity of attacking and destroying a Union ironclad in the summer and fall of 1863, coupled with the bounty on Union ships offered by businessmen such as Charlestonian B. A. Whitney should be seen as strong causal factors precipitating the September 1863 attack by *David* against *New Ironsides*. Dahlgren's instant appreciation of the potential menace to the Union blockade and the defensive measures he ordered following the attack made the inner cordon of the Union blockade a difficult target and drew Dixon and the third crew of *H.L. Hunley* further offshore to the less formidably armored and defended *Housatonic*.

David's attack against *New Ironsides* demonstrated that torpedo charges needed to be bigger and that they needed to be delivered lower on the hull. This was a lesson easily appreciated by Alvah Hunter, a ship's boy on USS *Nahant* (Chapter 2), and it most certainly was appreciated by the men whose professional existence was directed at the destruction of the federal blockade. A vertical spout of water resulting from the *David* attack indicated that much of the explosive force from the torpedo was dissipated upwards with negligible effect on the Union ship. When Dixon finally made his attack on *Housatonic*, he placed the charge well under the turn of the hull at the stern, which ensured that any upwards force resulting from the explosion was not dissipated but directed into the structure of the hull. This tactical refinement may have been the result of a careful analysis of *David*'s attack on *New Ironsides* in October 1863, and it bore

spectacular fruits during *Hunley's* attack on February 17, 1864.

While it is true that ultimately *Hunley's* attack on *Housatonic* had a relatively minor effect on the blockade of Charleston, had Dixon and his crew returned to their waiting compatriots on shore, things would have been different. Ralph Wilbanks, one of the archeologists who first discovered *Hunley* in 1995, notes that had *Hunley* avoided the unknown catastrophe that apparently befell it following the sinking of *Housatonic*, Southern confidence in the effectiveness of submarines might have led to their widespread use and a refinement of the tactics guiding their deployment (personal communication 2001). If Admiral Dahlgren's fears that the harbor would be "...infested with these cheap, convenient and formidable defenses" (ORN vol. 15:229–30) had become a reality, the Union's military costs for keeping a close blockade of Charleston would have risen dramatically. With a victorious crew safely back in Charleston and a Union sloop-of-war a total loss offshore, it may have been possible, albeit not easy, for Southern propagandists to declare to the European powers that the blockade had been raised by a new and powerful secret weapon—particularly in light of existing interest in submarines by European intelligentsia such as Jules Verne.

In the end, a Southern naval victory off Charleston had to be followed by a political victory in Europe to have decisive results for the Confederacy. The ultimate, yet distant, prize for which Dixon and his crew were playing was explicit political recognition for the Confederate States of America by foreign governments in general, but by Britain and France in particular. Official European involvement in the Civil War never lived up to Southern hopes, however, and by February 1864, Europe had already watched idly as the Confederacy suffered bitter defeats

at Vicksburg, Chattanooga and, perhaps most important, Gettysburg.

As the military power of the South slowly wilted under the dual effects of the North's increasingly efficient naval blockade and capacities of industrial production, the possibility that the Confederacy could woo political support from abroad became more and more remote. Though the bloodshed would continue for another 14 months following *Hunley's* attack, the end was becoming apparent to all. In Britain, Southern emissaries maneuvered in vain to gain an audience with the Foreign Secretary who had consistently refused to see them following two meetings in summer 1861 (McPherson 1988:389). France, though more predisposed to the Southern cause than England, would not make a move towards overt recognition of the Confederacy in the absence of a similar move by Britain. In the final analysis, while the safe return of Dixon and his crew would have made them wealthy heroes and given Confederate morale and submarine building a huge boost, it is doubtful that this tactical victory could have been successfully parlayed into a political victory in light of the broader course of the war in 1863 and early 1864. Lieutenant Dixon's victory, although a remarkable and courageous act, was too little and too late.

An analysis of testimony delivered at the Court of Inquiry convened following the destruction of the Union blockader, combined with an examination of the internal arrangement of the ship, paints a picture of a skillful and precisely executed attack that delivered a single, killing blow. The effectiveness of the 135-pound torpedo was probably magnified tremendously by secondary explosions in one or more of the *Housatonic's* magazines. Archeological evidence, in the form of systematic probing results on *Housatonic* and selected test excavations, indicates a missing or displaced

starboard stern which is likely the result of the *Hunley* attack. Agreement between the historical orientation of the ship at the time of its sinking and the position as documented archeologically indicates the ship moved little, if at all, following its sinking.

Ultimately, the sophistication of the Confederate attack mirrors the sophistication of *H.L. Hunley* as a piece of engineering and demonstrates a commanding grasp of both technology and tactics that capitalized on Southern advantages of initiative and surprise in the face of Union naval superiority. Both in structure and in execution, *Hunley*'s attack presaged naval special operations by groups such as the SEALs and Special Boat Units by almost exactly 100 years. Given modern perceptions that the North was industrialized and sophisticated while the South agrarian and backward, it is interesting to note that *Hunley*, arguably the most advanced weapon deployed during the conflict, was built and operated by the Confederacy.

CONCLUSIONS

Hunley sank very close to its last observed position about 50 minutes after attacking *Housatonic*. Following sinking, both *Hunley* and *Housatonic* scoured rapidly through the unconsolidated layers of sand on the floor of Charleston Harbor. As they hit the firmer layer of Pleistocene clay, settling of the wrecks slowed and then stopped. *Housatonic* was extensively salvaged in the years that followed, and in 1909, it was dynamited and dragged to the seabed to remove it as a navigation hazard. At the same

time, the buoy that marked it was probably sunk because it was no longer needed. The sunken buoy experienced the same scouring and settling sequence as the two wrecks, but, due to its diameter, has not yet been completely buried by sediment accretion. Completion of the Charleston jetties by the US Army Corps of Engineers in 1908 diverted longshore sediment transport offshore and resulted in the net accumulation of 4 ft. (1.2 m) over *Housatonic* and 3 ft. (.9 m) over *Hunley*. This sediment accumulation completely buried both wrecks, and ^{210}Pb radiometric dating indicates that sediment accumulation over both wrecks was continuous and not punctuated by periods of erosion.

Despite extensive salvage and decay, the *Housatonic* wreck has both structural integrity and contains well-preserved artifacts that can contribute to an understanding of the Union side of the *Hunley/Housatonic* naval engagement. The wreck, though completely buried and in a very difficult environment for archeology, displays coherence and promise for future research.

The Fourth Anomaly is a small, Admiralty-type anchor. It is probably contemporaneous with *Hunley* and *Housatonic*, but cannot be conclusively linked to either of these vessels, nor to the buoy at the Third Anomaly.

Analysis of sediments surrounding and underlying *H.L. Hunley* produced data indicating they did not possess sufficient strength to guarantee the submarine could be recovered encased in its surrounding matrix. As a result, a different recovery methodology was developed and successfully executed on August 8, 2000.

CHAPTER 10

Conclusions and Recommendations

David L. Conlin

CONCLUSIONS

Remote sensing data gathered during the 1996 joint National Park Service (NPS)/Naval Historical Center (NHC)/South Carolina Institute of Archaeology and Anthropology (SCIAA) assessment of *H.L. Hunley* and a multidisciplinary research design for a wide-area, GIS-based product, provided a framework for the subsequent 1999 assessment of the *H.L. Hunley*/USS *Housatonic* Naval Engagement Site. The 1999 fieldwork flowed logically from, and added to, research domains, data and questions generated during 1996, which focused on the *Hunley* Site. The cumulative nature of this work contributed to an understanding of historical, archeological and natural processes affecting *all* components of this multicomponent site that would not have been possible without an explicit statement of underlying assumptions and research foci in both 1996 and 1999.

Use of a GIS-based research approach during all phases of work done on the *Hunley*/*Housatonic* site allowed project principals to

rapidly assimilate information from the field and compare it to multiparameter data sets from earlier research and other sources. This cumulative GIS-based approach initiated by the Submerged Resources Center (SRC) in 1992 was an important part of a research design that emphasized the importance of maximizing information and data returns from minimum impact to archeological sites largely stabilized in environmental equilibrium. Geo-referenced data, displayed by GIS software, contributed directly to the success of this work and facilitated an approach that produced information pertaining to *Hunley*'s attack on *Housatonic*, site formation processes, the nature of outlying magnetic anomalies, and the physical integrity of *Housatonic* derived from the disturbance of approximately 0.02% of the total area surveyed during 1996.

Based upon probe and excavation data, the starboard stern quarter of the *Housatonic* wreck is displaced or missing. This is probably the direct or indirect result of the precise and skillful Confederate attack in the submarine *H.L. Hunley*

on the night of February 17, 1864. Following the attack, *Housatonic* was salvaged and lowered, but test excavations indicate that approximately 30% of the hull is still intact, articulated and well preserved under at least 4 ft. (1.3 m) of sediment. Relatively delicate organic artifacts such as shoes and a pencil that were recovered from the wreck show superior preservation and speak to the experiences of the blockade shared by Americans from both North and South.

The Third Anomaly lying between the wreck of *H.L. Hunley* and the wreck of *Housatonic* is a buoy that probably marked *Housatonic* as a navigation hazard prior to its final lowering in 1909. The Fourth Anomaly is an anchor that cannot be conclusively linked to *Hunley*, *Housatonic* or the Third Anomaly buoy.

After sinking, *Hunley*, *Housatonic* and the Third Anomaly buoy settled rapidly through the unconsolidated layers of sandy-silt until they contacted the firmer underlying layer of Pleistocene marl. Completion of the Charleston jetties in 1908 diverted longshore sediment transport offshore and buried the still exposed portions of both the *Hunley* and *Housatonic* wrecks beneath 3 and 4 ft. (.9 and 1.3 m) of sediments respectively. The buoy is also being buried, but due to its large diameter it has not yet been fully covered.

Archeological investigations of magnetic data generated during 1996 fieldwork indicate that a 2-gamma gradient reveals anomalies corresponding to archeological materials buried up to 5 ft. (1.5 m) deep in the sediment. This observation indicates that other, as yet undocumented, archeological materials lie within the boundaries of the 1996 survey area. These materials can be located and examined using the now proven techniques developed during 1999 fieldwork, which combine GIS, GPS, hand magnetometer, probing and precise test excavations.

The *H.L. Hunley*/USS *Housatonic* Naval Engagement Site is eligible for the National Register of Historic Places under criteria of significance A, B and D (National Register Bulletin 20:5-6). In general: "To be eligible for the National Register of Historic Places, a vessel must be significant in American history, architecture, archeology, engineering, or culture, and possess integrity of location, design, setting, materials, feeling, and association" (National Register Bulletin 20:5). Criterion A states that it should: "be associated with events that have made a significant contribution to the broad patterns of our history" (National Register Bulletin 20:5). Category 11, under Criterion A, encompasses naval warships and other vessels, military transports and support craft, while Category 8 encompasses vessels that were the result of a scientific process of experimentation, and Category 4 encompasses vessels important for technological developments in hull form, propulsion systems and shipboard equipment. In 1903, William Alexander, one of the engineers who designed and built *H.L. Hunley*, wrote that George Dixon and his crew:

...were the first, so far as history records, in all the world to demonstrate the possibility of successfully operating a submarine torpedo boat, years before much attention had been given to the subject. The *Hunley* accomplished the purpose for which a submarine torpedo boat was designed, viz., to operate underwater at sea, exploding a torpedo under and sinking a war vessel of an enemy in time of war. By this event the subject of successfully operating submarine torpedo boats received an impetus, moving the governments of every nation to make them important auxiliaries to their fleets. The plans of all the modern productions of submarine

torpedo boats, when compared with the *Hunley*, are copied from the *Hunley*. Submarine navigation arrived with the *Hunley* forty years ago, and the *Hunley* was a product of Mobile—a city in the South [Campbell 2000:116].

The wreck of USS *Housatonic* is the direct result of *H.L. Hunley*'s attack and it, along with associated objects, is the world's first material signature of a mode of warfare that continues to influence global strategy and geopolitics today. *Housatonic* is important not only as the Union side of this historic naval engagement but also as the remains of a ship resulting from the rapid build-up of Northern naval forces to enforce President Lincoln's blockade. This rapid industrialization of naval shipbuilding was a process repeated in both World Wars, was in part responsible for victories in all three conflicts, and is an important aspect of American and world history. While the *Housatonic* design was a modification of the earlier *Mohican* class, the steam machinery on board is the result of naval engineer Benjamin Isherwood's innovative ideas concerning this relatively new means of propulsion. Technologically, therefore, *Housatonic* stands at the early transition from warships powered by sails and the mature technology of late nineteenth century steam power.

Criterion B states that the site: "be associated with the lives of persons significant in our past" (National Register Bulletin 20:5). The *H.L. Hunley*/USS *Housatonic* Naval Engagement Site is associated with the prominent Southern inventors Horace Lawson Hunley, James McClintock and Baxter Watson; Confederate General P. G. T. Beauregard; Confederate naval commander John Tucker and Union Admiral John Dahlgren. *Housatonic* in and of itself is directly related to the well-known naval engineer Benjamin Isherwood. This naval

engagement site is the result of the conflicting intentions and actions that each of these men orchestrated during the blockade of Charleston from 1861 to 1864, and it is the direct result of the inventiveness of Hunley, Watson and McClintock.

Criterion D states that the site: "have yielded, or may be likely to yield, information important in prehistory or history" (National Register Bulletin 20:6). The *H.L. Hunley*/USS *Housatonic* Naval Engagement Site represents the results of the deployment of what was arguably the single most sophisticated weapon of the American Civil War. In contrast to contemporary assumptions about an agrarian South and a technologically sophisticated North, the *Hunley* attack shows that, faced with a military disadvantage, technological inventiveness can flourish and be effectively deployed to take advantage of conditions of surprise and initiative. This perspective stands in direct opposition to how many may view the conflict. The Confederacy's construction and deployment of *H.L. Hunley* reflects an underlying American preoccupation with technology as a response to conflict, while its continued employment, despite two catastrophic sinkings, resonates with widely held national values of courage, self-sacrifice and determination in the face of adversity. Because the submarine was developed and deployed largely in secret, there are few historical documents associated with it—making archeological investigation the best way to augment the scarce documents that address this pivotal moment in world history.

RECOMMENDATIONS

1. Artifacts recovered from the wreck of *Housatonic* should be fully integrated into the *H.L. Hunley* display to reflect the engagement as an event significant to and affecting

Americans from both North and South. The simple dignity of everyday objects such as shoes and a pencil illuminate the daily life of ordinary sailors and emphasize common experiences for both sides that will help soothe wounds that remain tender even after 136 years.

2. The *H.L. Hunley*/USS *Housatonic* Naval Engagement Site is a significant part of national and international history and should be nominated to the National Register of Historic Places based upon the criteria outlined above. Site boundaries should encompass at least the 1996 survey area. Due to the burial of archeological materials and the sturdiness of the small portion of the Third Anomaly buoy that remains exposed, a National Register Nomination need not interfere with the economic livelihood of Charleston's commercial shrimp fishermen. Though *Hunley* was successfully recovered in August 2000, magnetic data indicate that other artifacts may remain close to the original wreck location. In addition, the point where *Hunley* sank to the bottom and nine men lost their lives is important in the interpretation of the engagement, and this area should therefore be included in a National Register nomination.

3. Further excavation work on the wreck of USS *Housatonic*, as well as other magnetic anomalies, should be considered. Excavations designed to confirm inferences concerning the damage resulting from *Hunley*'s attack should be planned and additional artifacts relating to the other half of the engagement should be recovered to further illuminate the Union side of the attack. Excavation north of the water tanks in Trench 2 will produce more personal artifacts from the sailors of *Housatonic* that have fallen from the berth deck above, and this will contribute to an understanding of the social aspects of the blockade. Because a geo-referenced hull plan for *Housatonic* (based on *Ossipee*) has been integrated into the GIS

database, future investigators can precisely and accurately select an area of the hull for excavation based upon research designs and interpretive requirements without having to disturb areas not immediately relevant. Themes explored during 1996 and 1999 continue to hold promise for further development and should be continued within an explicitly delineated framework of science-based archeological investigation.

4. A project to document the wreck of *Housatonic*'s sister ship, USS *Adirondack*, which wrecked on August 23, 1862, while in pursuit of the Confederate raider CSS *Oreto* on the northeast point of Little Bahama Bank, Man of War Cay, Bahamas, should be considered. *Adirondack* will furnish comparative materials for the *Ossipee* class; the working environment should be much more benign; and it may be possible to extensively document surviving steam machinery. A longitudinal study of this vessel class will document variations between different ships that may provide insight into the larger processes involved in America's first industrial production of warships.

5. *Hunley*'s attack on the night of February 17, 1864, killed 14 men—nine from *H.L. Hunley* and five from USS *Housatonic*. Taken in the context of a conflict that killed an estimated 600,000 Americans, the number is not itself significant, but lacking an ability to comprehend what 600,000 deaths actually means, perhaps the *H.L. Hunley*/USS *Housatonic* engagement can serve as a vignette of the larger drama and tragedy that swept the nation for four bloody years. Union casualties resulting from the *Hunley* attack—Ensign E. C. Hazeltine, Captain's Clerk C. O. Muzzey, Quartermaster John Williams, Landsman Theodore Parker and Second-Class Fireman John Walsh—should be commemorated in the same manner as the Confederate casualties—Arnold Becker, C. Simkins, James Wicks, F. Collins, Ridgeway,

Corporal C. F. Carlson and Lieutenant George Dixon. Both Union and Confederate losses resulting from the attack on February 17, 1864, should be included in all public interpretations.

6. The *Housatonic* wreck should be treated with the dignity, honor and respect due a military

grave site and actively managed by the agencies with jurisdictional responsibilities and interests. A multiagency management plan should be developed directed toward the long-term preservation and interpretation of *Housatonic* and the entire Naval Engagement Site.



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REFERENCES

- Allston, F. J.**
1995 *Ready for Sea. The Bicentennial History of the U.S. Navy Supply Corps.* Naval Institute Press, Annapolis.
- American Shipmaster's Association**
1879 *Standard Classification of American Vessels.* New York.
- Argyropoulos, V., L. S. Selwyn and J. A. Logan**
1997 Developing a Conservation Treatment Using Ethylenediamine as a Corrosion Inhibitor for Wrought Iron Objects Found at Terrestrial Archaeological Sites. In *Metal 95. Proceedings of the International Conference on Metals Conservation*, edited by I. D. MacLeod et al., p. 153-158. James & James, London.
- Bak, R.W.**
1999 *The CSS Hunley.* Taylor Publishing, Dallas.
- Belknap, D. F. and J. C. Kraft**
1985 Influence of Antecedent Geology on Stratigraphic Preservation Potential and Evolution of Delaware's Barrier System. *Marine Geology* 63:235-262.
1981 Preservation Potential of Transgressive Coastal Lithosomes on the U.S. Atlantic Shelf. *Marine Geology* 42:429-442.
- Bennett, F. M.**
1896 *The Steam Navy of the United States.* Warren and Company, Pittsburgh.
- Bingeman, J. M., J. P. Bethell, P. Goodwin, and A. T. Mack**
2000 Copper and Other Sheathing in the Royal Navy. *International Journal of Nautical Archaeology* 29:218-229.
- Black, F. R. and E. C. Bearss**
1993 *The Charlestown Navy Yard 1842-1890.* National Park Service.
- Blackwelder, B. W., O. H. Pinkey and J. D. Howard**
1979 Late Wisconsinan Sea Levels on the Southeastern U.S. Atlantic Shelf Based on In-place Shoreline Indicators. *Science* Vol. 204, No. 4393:618-620.
- Boger, L. A.**
1971 *The Dictionary of World Pottery and Porcelain.* Charles Scribner's Sons, New York.
- Bonnot-Diconne, C., X. Hiron, Q. K. Tran and P. Hoffman (editors)**
1999 *Proceedings of the 7th ICOM-CC Working Group on Wet Organic Archaeological Materials Conference, Grenoble/France 1998.* ARC-Nucleart, Grenoble.
- Boston Daily Advertiser**
1861 21 November.

Boston Traveler

1937 17 September.

Brennan, J. W.

1991 Meteorological Summary of Hurricane Hugo. *Journal of Coastal Research* Special Edition 8:1-12.

Bradlee F. N.

1974 *Blockade Running During the Civil War*. Porcupine Press, Philadelphia.

Brostoff, L. B.

1997 Investigation into the Interaction of Benzotriazole with Copper Corrosion Minerals and Surfaces. In *Proceedings of the International Conference on Metals Conservation*, edited by I. D. MacLeod and , p. 99-108. James & James, London.

Brybaert, A.

1999 Conservation Problems and Decisions Involved in the Treatment of a Waterlogged "Sickle" from Shinewater Park-Eastbourne (UK). In *Proceedings of the 7th ICOM-CC Working Group on Wet Organic Archaeological Materials Conference, Grenoble/France 1998*, edited by C. Bonnot-Diconne and p. 173-178. ARC-Nucleart, Grenoble.

Burton, E. M.

1970 *The Siege of Charleston*. University of South Carolina Press, Columbia.

Buys, S. and V. Oakley

1993 *Conservation and Restoration of Ceramics*. Butterworth-Heinemann, Oxford.

Campbell, R. T.

2000 *The CSS H.L. Hunley*. Burd Street Press, Shippensburg, Pennsylvania.

Canadian Conservation Institute

1997 Tannic Acid Treatment. *CCI Notes* 9/5. Canadian Conservation Institute, Ottawa.

Canney, D. L.

1990 *The Old Steam Navy* Vol. 1. Naval Institute Press, Annapolis.

Chapelle, H. L.

1967 *The Search for Speed Under Sail*. Bonanza Books, New York.

Charleston Daily Courier

1861 24 January.

1863 7 May.

1864 15 March.

Charleston Mercury

1864 3 March.

Charleston News and Courier

1908 12 July.

Churchill, W. S.

1995 *Churchill's History of the English Speaking Peoples*. Arranged for one volume by Henry Steele Commager. Barnes & Noble, New York.

Clavir, M.

1982 An Initial Approach to the Stabilization of Rubber from Archaeological Sites and in Museum Collections. *Journal of the International Institute for*

- Conservation – Canadian Group* 7: 3–10.
- Colquhoun, D. J., M. J. Brooks, J. Michie, W. B. Abbott, F. W. Stapor, W. Newman and R. Pardi**
1981 Location of Archaeological Sites with Respect to Sea Level in the Southeastern United States. *Stria* 14:145–150.
- Colquhoun, D. J., G. H. Johnson, P. C. Peebles, P. F. Huddleston and T. Scott**
1991 Quaternary Geology of the Atlantic Coastal Plain. In *The Geology of North America*, vol. K-2, edited by R. B. Morrison, pp. 629–650. Geological Society of America, Boulder.
- Colquhoun, D. J. and H. S. Johnson**
1967 Tertiary Sea-level Fluctuation in South Carolina. *Paleogeography, Paleoclimatology, and Paleoecology* 15:105–126.
- Commoner, L. A.**
1992 Storage Containers for Textile Collections. In *Conservation Concerns: A Guide for Collectors and Curators*, edited by K. Bachmann, p. 91–96. Smithsonian Institution Press, Washington, DC.
- Cooke, C. W.**
1930 Correlation of Coastal Terraces. *Journal of Geology* 38:577–589.
- 1936 Geology of the Coastal Plain of South Carolina. *U.S. Geological Survey Bulletin No. 867*, p. 196.
- Corbett, J. S.**
1938 *Some Principles of Maritime Strategy* [1911] Longmans, Greene and Co., New York.
- Curryer, B. N.**
1999 *Anchors: An Illustrated History*. Naval Institute Press, Annapolis.
- Cyclopaedia of Useful Arts**
1854 *Anchors*. Typescript on file at San Francisco Maritime National Historic Park, San Francisco.
- Department of the Army**
1990 Myrtle Beach and Vicinity, South Carolina. Communication from the Assistant Secretary of the Army, October 10, 1990. 101st Congress, 2^d Session, *House Document*, pp.101–248, 383. Washington, DC.
- Desmond, C.**
1984 *Wooden Ship-Building*. Vestal Press, New York.
- Dickey, T. S. and P. C. George**
1993 *Field Artillery Projectiles of the American Civil War*. Arsenal Publications, Mechanicsville, VA.
- English Heritage**
1995 *Guidelines for the Care of Waterlogged Archaeological Leather*. English Heritage Scientific and Technical Guideline No. 4. English Heritage, London.
- Enright, J. F and J. W. Ryan**
1987 *Sea Assault*. St. Martin's Press, New York.

- Fairbanks, R. G.**
1989 A 17,000-year Glacio-eustatic Sea Level Record: Influence of Glacial Melting Rates on the Younger Dryas Event and Deep-ocean Circulation. *Nature*, 342:637-642.
- FitzGerald, D. M., C. Fico and M. O. Hayes**
1979 Effects of the Charleston Harbor, S.C. Jetty Construction on Local Accretion and Erosion. *Proceedings of the Conference on Coastal Structures*, 23 pp. American Society of Civil Engineers, Washington, DC.
- Fox, G.**
1995 A Note on the Use of Alkaline Dithionite for Treating Ancient Bronze Artifacts. *Studies in Conservation* 40:139-142.
- Ganiaris, H. S. Keene and K. Starling**
1982 A Comparison of Some Treatments for Excavated Leather. *The Conservator* 6:12-23.
- Gayes, P. T.**
1991 Post-Hurricane Hugo Nearshore Side Scan Sonar Survey; Myrtle Beach to Folly Beach, South Carolina. *Journal of Coastal Research* Special Issue no. 8:95-111.
- Gohn, G., B. B. Houser and R. R. Schneider**
1983 Geology of the Lower Mesozoic Sedimentary Rocks in Clubhouse Crossroads Test Hole #3, Near Charleston, South Carolina. In *Studies Related to the Charleston, South Carolina, Earthquake of 1886: Tectonics and Seismicity*, edited by Gregory S. Gohn, pp. D1-D17, US Geological Survey Professional Papers 1313.
- Goodwin, P.**
1987 *The Construction and Fitting of the English Man of War 1650-1850*. Conway Maritime Press, London.
- Haecker, C. and J. G. Mauck**
1994 *On the Prairie of Palo Alto: Historical Archaeology of the U.S.-Mexican War Battlefield*. Texas A&M University Press, College Station.
- Hall, H.**
1970 *Report on the Ship-building Industry [1884] of the United States*. Library Editions, New York.
- Harris, M. S. and A. Askins**
1998 Environmental Context. In *H.L. Hunley Site Assessment* edited by Larry Murphy. National Park Service, Santa Fe.
- Harris, M. S., P. T. Gayes, J. L. Kindinger, J. G. Flocks, M. P. Katuna, J. F. Wehmiller and D. E. Krantz**
1997 Short- and Long-term Geomorphic Evolution of the Central South Carolina Coastal Zone: Coastal Response to a Complex Geologic Framework. Fall meeting of the American Geophysical Union, *EOS Transactions* 78(46):F334.
- Harris, M. S., D. E. Krantz, J. F. Wehmiller, P. T. Gayes, J. I. Kindinger and J. Flocks**
1994 High resolution stratigraphy and paleogeography of the upper Cenozoic system Beneath the Coastal Plain and Continental Shelf, Charleston, SC.

- Geological Society of America Abstracts with Programs, National Meeting, Denver, October 1996*, Vol 28(7), p. A118.
- Harris, M. S., P. T. Gayes and P. Donovan-Ealy**
1994 Influence of Cenozoic Deposits on the Coastal Evolution of the South Carolina Inner Shelf and Coastline. *Geological Society of America Abstracts with Programs*, Vol. 26, 7:153.
- Hay, W. J.**
1863 On Copper and Other Sheathing for the Navy. *Transactions of the Institution of Naval Architects* 4:79-98, London.
- Hayes, M. O.**
1979 Barrier Island Morphology as a Function of Tidal and Wave Regime. In *Barrier Islands from the Gulf of St. Lawrence to the Gulf of Mexico* edited by S. P. Leatherman. Academic Press, New York.
- Hayes, M. O., T. F. Moslow and D. K. Hubbard**
1984 *Beach Erosion in South Carolina*. US Department of Commerce, Washington, DC.
- Hovmand, I. and J. Jones**
2001 Experimental Work on the Mineral Content of Archaeological Leather. In *Leather Wet and Dry. Current Treatments in the Conservation of Waterlogged and Desiccated Archaeological Leather*, edited by B. Willis, p. 27-36. Archetype Publications, London.
- Hume, I. N.**
1969 *A Guide to Artifacts of Colonial America*. University of Pennsylvania Press, Philadelphia.
- Hunter A. F.**
1987 *A Year on a Monitor and the Destruction of Fort Sumter*. University of South Carolina Press, Columbia.
- Johnson, J.**
1890 *The Defense of Charleston Harbor*. Charleston.
- Kana, T.**
1988 *Beach Erosion in South Carolina*. South Carolina Sea Grant Consortium, Charleston.
- Katuna, M. P.**
1991 The Effects of Hurricane Hugo on the Isle of Palms, South Carolina: From Destruction to Recovery. *Journal of Coastal Research* Special Issue No. 8:263-273.
- Lenihan, D. J. and L. E. Murphy**
1998 Research Design. In *H.L. Humley Site Assessment* edited by Larry E. Murphy. National Park Service, Santa Fe.
- Leskard, M.**
1987 The Packing and Transportation of Marine Archaeological Objects. In *Conservation of Marine Archaeological Objects*, edited by C. Pearson, C 7. Butterworths, London.
- Loadman, M. J. R.**
1993 Rubber: Its History, Composition and Prospects for Conservation. In

- Saving the Twentieth Century: The Conservation of Modern Materials. Proceedings of a Conference Symposium '91—Saving the Twentieth Century, Ottawa, Canada, 15 to 20 September 1991*, edited by D. W. Grattan, p. 59–80, Canadian Conservation Institute, Ottawa.
- Lord, F. A.**
 1963 *Civil War Collector's Encyclopedia*. The Stackpole Company, Harrisburg.
 1975 *Civil War Collector's Encyclopedia*. Lord Americana & Research, W. Columbia.
- Lowder, H. E. and J. Scott**
 1980 *Batfish: The Champion "Submarine-Killer" Submarine of World War II*. Prentice-Hall, Englewood Cliffs, New Jersey.
- MacMahan, J.**
 1997 Comparative Wave Characteristics on Two Beaches in South Carolina. Fall meeting of the American Geophysical Union, EOS Transactions 78(46):F333.
- McAulay, J. D.**
 1992 *Civil War Pistols of the Union*. Andrew Mowbray Inc., Lincoln, RI.
- McCartan, L., R. E. Weems and E. M. Lemon, Jr.**
 1979 The Wando Formation (Upper Pleistocene) in the Charleston, South Carolina, Area. *Changes in Stratigraphic Nomenclature by the U.S. Geological Survey: Geological Survey Bulletin 1502-A*: A110–A116.
- McCarthy, M.**
 1996 Ships Fastenings: a Preliminary Study revisited. *International Journal of Nautical Archaeology* 25:177–206.
- McPherson, J. M.**
 1988 *Battle Cry of Freedom*. Ballantine Books, New York.
- Melton, J. W. Jr. and L. E. Pawl**
 1996 *Melton & Pawl's Guide to Civil War Artillery Projectiles*. Kennesaw Mountain Press, Kennesaw, GA.
- Moore, J.**
 1980 *The Low-Country Engineers*. US Army Corps of Engineers, Charleston.
- Murphy, L. E. (editor)**
 1998 *H.L. Hunley Site Assessment*. National Park Service, Santa Fe.
- Murphy, L. E., D. J. Lenihan and C. F. Amer**
 1998 Conclusions and Recommendations. In *H.L. Hunley Site Assessment* edited by Larry E. Murphy. National Park Service, Santa Fe.
- Murphy, L. E., M. A. Russell and C. F. Amer**
 1998 Site Description. In *H.L. Hunley Site Assessment* edited by Larry E. Murphy. National Park Service, Santa Fe.
- Murphy, L. E., M. A. Russell, T. G. Smith and S. M. Shope**
 1997 Shipwrecks, Satellites, and Computers: An Underwater Inventory of Our National Parks. *Common Ground* 1(3/4):47–51.
 1998 Predisturbance Remote Sensing Survey. In *H.L. Hunley Site*

- Assessment* edited by Larry E. Murphy. National Park Service, Santa Fe.
- Murphy, L. E. and T. G. Smith**
1995 Submerged in the Past: Mapping the Beguiling Waters of Florida's Biscayne and Dry Tortugas National Parks. *GeoInfo Systems* 5(10):26-33.
- Musicant, I.**
1994 *Divided Waters*. Harper Collins, New York.
- Nantucket Historical Association**
1980 The Destruction of the U.S.S. 'Housatonic' During The Civil War. *Historic Nantucket* 27.3:27-31. Nantucket Historical Association, Nantucket.
- National Archives**
1863- USS *Canandaigua* logbook, July 11,
1864 1863 to July 8, 1864. National Archives, Washington, DC.
- n.d. Letter Books of the Officers of the United States Navy at Sea, Record Group 45, Entry M625, Area 8. National Archives, Washington, DC.
- n.d. Letters received by the Secretary of the Navy from Squadron Commanders, Record Group 25, M89. National Archives, Washington, DC.
- n.d. Professor Benjamin Maillefert's Salvage Logs. South Carolina Historical Society, Charleston.
- n.d. Miscellaneous Wrecks, 1871-1888, Record Group 77, File #1125. National Archives, Southeast Region, Atlanta.
- n.d. Area file of Naval Records collection, Record Group 45, M625, Area 8, Reel 208. National Archives, Washington, D.C.
- n.d. ZC files. Navy Historical Center, Washington, DC.
- National Park Service**
1971 *The Story of A Civil War Gunboat. USS Cairo*. National Park Service, Washington, DC.
- National Register Bulletin**
1992 National Register Bulletin 20: Nominating Historic Vessels and Shipwrecks to the National Register of Historic Places. National Park Service, Washington DC.
- Navy Department**
1864 *Ordnance Instructions for the United States Navy*. Third ed. Government Printing Office, Washington, DC.
- 1865 *Allowances Established for Vessels of the United States Navy 1864*. Government Printing Office, Washington, DC.
- Naval History Department**
1894 *Official Records of the Union and Confederate Navies in the War of the Rebellion*. US Government Printing Office series I, Vols. 1-27; series II, Vols 1-3 (1894-1922), Washington DC.
- 1959- *Dictionary of American Naval*
1991 *Fighting Ships*. Naval History Department, 8 vols., Washington, DC.
- Northeast Document Conservation Center**
1992 Encapsulation in Polyester Film using Double-coated Tape. In *Storage of*

- Natural History Collections: Ideas and Practical Solutions*, edited by C. L. Rose and A. R. de Torres, Vol. II, p. 137-139. Society for the Preservation of Natural History Collections, Iowa City.
- Ogilvie, T. and D. Sully**
1997 Panel Discussion on Waterlogged Leather. In *Proceedings of the 6th ICOM Group on Wet Organic Archaeological Materials Conference, York 1996*, edited by P. Hoffman and p. 587-596. ICOM-WOAM, Bremerhaven.
- Office of the Chief of Naval Operations**
1971 *Civil War Naval Chronology*. Naval History Department, Washington, DC.
- Paasch, H.**
1997 *Paasch's Illustrated Marine Dictionary*. Conway Maritime Press, New York.
- Pearson, C. (editor)**
1987 *Conservation of Marine Archaeological Objects*. Butterworths, London.
- Peterson, H. L.**
1969 *Round Shot and Rammers*. Bonanza Books, New York.
- Petroski, H.**
1990 *The Pencil. A History of Design and Circumstance*. Alfred A. Knopf, New York.
- Poag, C. W.**
1984 Neogene Stratigraphy of the Submerged U.S. Atlantic Margin. In *Palaeogeography, Palaeoclimatology, Palaeoecology* 47:103-127.
- Popenoe, P. H.**
1986 Paleo-oceanography and Paleogeography of the Miocene of the Southeastern United States. In *World Phosphate Deposits: Neogene Phosphorites of the Southeastern United States*, edited by W. C. Burnett and S. R. Riggs, pp.352-380. Cambridge University Press, Cambridge.
- Popenoe, P. H., J. Vernon and F. M. Idris**
1987 Gulf Trough: the Atlantic Connection. *Geology* (Boulder), vol. 15, no. 4, pp. 327-332.
- Porter, D. D.**
1985 *Naval History of the Civil War*. Castle, Secacus.
- Ragan, M. K.**
1995 *H.L. Hunley: Submarines Sacrifice and Success in the Civil War*. Narwal Press, Charleston.
1999 *Union and Confederate Submarine Warfare in the Civil War*. Savas, Mason City, Iowa.
- Scott, D. D. and R. A. Fox**
1987 *Archaeological Insights into the Custer Battle*. University of Oklahoma Press, Norman.
- Scott, D. D. and W. J. Hunt**
1998 *The Civil War Battle at Monroe's Crossroads*. National Park Service, Tallahassee.
- Selwyn, L. S. and J. A. Logan**
1993 Stability of Treated Iron: A Comparison of Treatment Methods. In *ICOM Committee for Conservation 10th Triennial Meeting Washington*,

- DC, USA, 22-27 August 1993, p. 803-807. ICOM Committee for Conservation, Paris.
- Shashoua, Y. and S. Thomsen**
1993 A Field Trial for the Use of Ageless in the Preservation of Rubber in Museum Collections. In *Saving the Twentieth Century: The Conservation of Modern Materials. Proceedings of a Conference Symposium '91 - Saving the Twentieth Century, Ottawa, Canada, 15 to 20 September 1991*, edited by D. W. Grattan, p. 363-372. Canadian Conservation Institute, Ottawa, Canada.
- Shattuck, G. B.**
1901 The Pleistocene Problem of the North Atlantic Coastal Plain. *American Geologist* 28:87-107.
- Sheng, Y. P.**
2000 Physical Characteristics and Engineering at Reef Sites. In *Artificial Reef Evaluation* edited by W. Seaman. CRC Press, Boca Raton.
- Shope, S. M., L. E. Murphy and T. G. Smith**
1995 Found at Sea: Charting Florida's Sunken Treasures. *GPS World* 6(5):22-34.
- Silverstone, P.**
1989 *Warships of the Civil War Navies*. Naval Institute Press, Annapolis.
- Simpson, Edward**
1862 *A Treatise on Ordnance and Naval Gunnery*. 2nd ed. D. van Nostrand, New York.
- Stauble, D. K., W. C. Seabergh and L. Z. Hayes**
1991 Effects of Hurricane Hugo on the South Carolina Coast. *Journal of Coastal Research* Special Issue No. 8:129-162.
- Steffy, J. R.**
1994 *Wooden Ship Building and the Interpretation of Shipwrecks*. Texas A&M University Press, College Station.
- Tarrant, V. E.**
1989 *The U-Boat Offensive 1914-1945*. Cassell, London.
- Taylor, T. E.**
1896 *Running the Blockade: A Personal Narrative of Adventures, Risks, and Escapes During the American Civil War*. John Murray, London.
- Tennent, N. H., T. Baird, and L. T. Gibson**
1996 The Technical Examination and Conservation of Blackened Delftware from Anaerobic Sites. In *Archaeological Conservation and Its Consequences. Preprints of the Contributions to the Copenhagen Congress, 26-30 August 1996*, edited by A. Roy and P. Smith, p.182-187. International Institute for Conservation, London.
- Terraine, J.**
1989 *Business in Great Waters*. London, Wadsworth.
- Tian, W.**
1994 Burial Mechanism for Artificial Reefs: a Geotechnical Point of View. In

Proceedings, 16th Conference on Ocean Engineering. Republic of China pp. D79-94.

Thompson, B. F.

1998 *The Terrible Calamity on the Lower Potomac. An Historical and Archaeological Assessment of the Shipwreck U.S.S. Tulip (18ST644), Potomac River, St. Mary's County, Maryland*. Maryland Maritime Archaeology Program File Report 003. Maryland Historic Trust, Crownsville, MD.

Todd, F. P.

1978 *American Military Equipage 1851-1872*. Charles Scribner's Sons, New York.

Tye, R. S. and T. F. Moslow

1993 Tidal Inlet Reservoirs: Insights from Modern Examples. In *Marine Clastic Reservoirs: Examples and Analogues*, edited by E. G. Rhodes, pp. 77-79. Springer-Verlag, New York.

US Army Corps of Engineers

1873 *Annual Report of the Chief of Engineer 1873*. US Government Printing Office, Washington, DC.

1909 *Annual Report of the Chief of Engineer 1909*. US Government Printing Office, Washington, DC.

US Department of the Navy

1921 Office of Naval War Records. *Official Records of the Union and Confederate Navies in the War of Rebellion*. Series II, Vol. 1. US Government Printing Office, Washington, DC.

1864 US Naval Regulations, *Uniform for Officers of the United States Navy, As Prescribed in Regulations for the Uniform of the U.S. Navy, Jan. 28, 1864*. Tomes, Melvain & Co., New York.

Van Dolah, R. F. and G. S. Anderson

1991 Effects of Hurricane Hugo on Salinity and Dissolved Oxygen Conditions in the Charleston Harbor Estuary. *Journal of Coastal Research* Special Issue No. 8:83-94.

Watkinson, D.

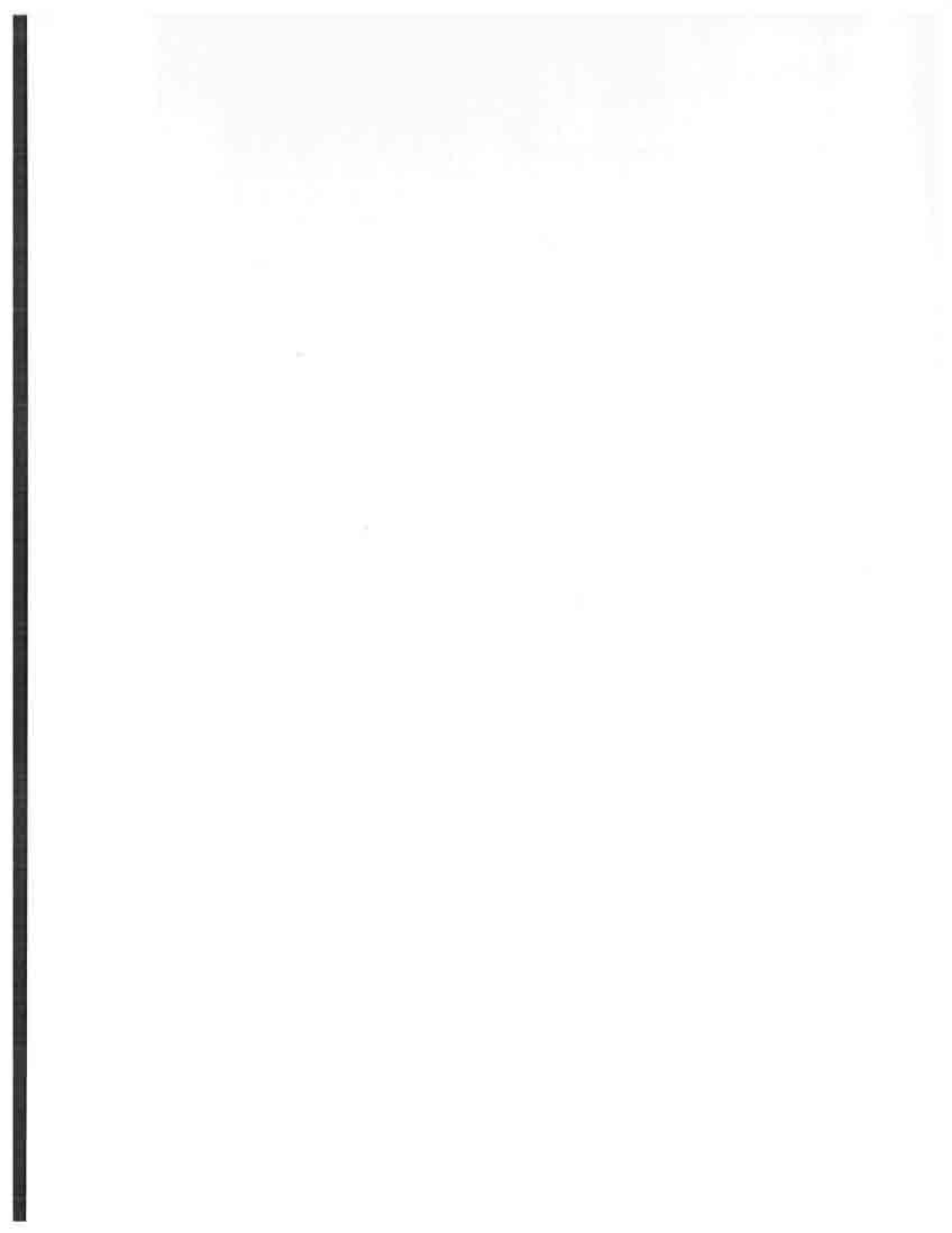
1982 An Assessment of Lithium Hydroxide and Sodium Hydroxide Treatments for Archaeological Ironwork. In *Conservation of Iron*, edited by R. W. Clarke and S. M. Blackshaw, pp. 28-40. Maritime Monographs and Reports No. 53. National Maritime Museum, Greenwich, England.

1996 Chloride Extraction from Archaeological Iron: Comparative Treatment Efficiencies. In *Archaeological Conservation and Its Consequences. Preprints of the Contributions to the Copenhagen Congress 26-30 August 1996*, edited by A. Roy and P. Smith, p. 208-212. International Institute for Conservation, London

Weems, R. E. and E. J. Lemon

1993 *Geology of the Cainhoy, Charleston, Fort Moultrie, and North Charleston Quadrangles, Charleston and Berkeley Counties, South Carolina*.

- USGS Miscellaneous Investigation Series, Map No. I1935.
- Welles, G.**
1862– Personal Ledger. National Archives,
1863 Washington DC.
- West, W. W.**
1997 *USS Tecumseh Shipwreck Management Plan*. Naval Historical Center, Washington, DC.
- Wetherbee, J.**
1996 *White Ironstone: A Collector's Guide*. Antique Trader Books, Dubuque, IA.
- Wills, B. (editor)**
2001 *Leather Wet and Dry. Current Treatments in the Conservation of Waterlogged and Desiccated Archaeological Leather*. Archetype Publications, London.
- Woodhead, H. (editor)**
1991 *Echoes of Glory: Arms and Equipment of the Union and Echoes of Glory: Arms and Equipment of the Confederacy*. Time-Life Publishers, Morristown, NJ.
- Zarillo, G. L. G. Ward and M. O. Hayes**
1985 *An Illustrated History of Tidal Inlet Changes in South Carolina*. South Carolina Seagrant, Charleston.
- Zeigler, J. M.**
1959 Origin of the Sea Islands of the Southeastern United States. *Geographical Review* 49(2):222–237.
- Zierden, M. A., S. D. Smith and R. W. Anthony**
1995 *Our Duty was Quite Arduous: History and Archaeology of the Civil War on Little Folly Island, South Carolina*. Charleston Museum Leaflet Number 32. Charleston Museum, Charleston.



APPENDIX A

Artifact and Sample Catalog

HOUSATONIC ARTIFACTS

| FIELD NO. | MATERIAL | OBJECT | STATUS | DATE RECOVERED | RECOVERED BY | LOCATION |
|---------------|----------------------|-------------------------------|--------------------|----------------|----------------|-------------------------|
| Hunhou 99-001 | steel, polypropylene | wire, rope | treated | 6/9/99 | Dave Conlin | 3 rd anomaly |
| Hunhou 99-002 | copper, lead, brass | dive weight | treated | 6/9/99 | Dave Conlin | 3 rd anomaly |
| Hunhou 99-003 | zinc | artillery fuse | in water | 6/9/99 | Dave Conlin | Trench 1 |
| Hunhou 99-004 | coal | lump | treated | 6/16/99 | Mark Ragan | Trench 1 |
| Hunhou 99-005 | coal | lump | treated | 6/16/99 | Bob Neyland | Trench 1 |
| Hunhou 99-006 | coal | lump | treated | 6/16/99 | Bob Neyland | Trench 1 |
| Hunhou 99-007 | coal | lump | treated | 6/16/99 | David Whall | Trench 1 |
| Hunhou 99-008 | wood | wood plank fragment (1) | treated | 6/16/99 | David Whall | Trench 1 |
| Hunhou 99-009 | zinc | artillery fuse | in water | 6/16/99 | David Whall | Trench 1 |
| Hunhou 99-010 | concretion | sample | not to be treated | 6/17/99 | Claire Peachey | Trench 1 |
| Hunhou 9-0011 | zinc | artillery fuse | in water | 6/17/99 | Dave Conlin | Trench 1 |
| Hunhou 99-012 | lead, brass | weight | treated | 6/17/99 | Dave Grant | Trench 1 |
| Hunhou 99-013 | iron, wood | concretion | in NaOH | 6/17/99 | Dave Grant | Trench 1 |
| Hunhou 99-014 | wood | wood plank fragments (3) | treated | 6/17/99 | Chris Amer | Trench 1 |
| Hunhou 99-015 | coal | lump | treated | 6/17/99 | David Whall | Trench 1 |
| Hunhou 99-016 | coal | lump | treated | 6/17/99 | David Whall | Trench 1 |
| Hunhou 99-017 | iron | strap | not to be treated | 6/17/99 | David Whall | Trench 1 |
| Hunhou 99-018 | rubber | ring | treated | 6/17/99 | David Whall | Trench 1 |
| Hunhou 99-019 | coal | lumps, 3 | treated | 6/17/99 | Bob Neyland | Trench 1 |
| Hunhou 99-020 | iron | concretion | treatment inactive | 6/21/99 | Bob Neyland | Trench 1 |
| Hunhou 99-021 | wood | wood plank with dovetail ends | treated | 6/21/99 | Bob Neyland | Trench 1 |
| Hunhou 99-022 | wood | wood fragment | treated | 6/21/99 | Bob Neyland | Trench 1 |
| Hunhou 99-023 | wood | wood fragments, 2 | in PEG or f-d | 6/21/99 | Claire Peachey | Trench 1 |

| FIELD NO. | MATERIAL | OBJECT | STATUS | DATE RECOVERED | RECOVERED BY | LOCATION |
|---------------|------------------------|---------------------------|-----------------------|----------------|----------------|----------|
| Hunhou 99-024 | wood | wood fragments from log | treated | 6/21/99 | Claire Peachey | Trench 1 |
| Hunhou 99-025 | brass | trigger assembly | treatment inactive | 6/21/99 | Chris Arner | Trench 1 |
| Hunhou 99-026 | zinc | artillery fuse | in water | 6/21/99 | Brett Seymour | Trench 1 |
| Hunhou 99-027 | iron | concretion fragment | not to be treated | 6/21/99 | Brett Seymour | Trench 1 |
| Hunhou 99-028 | zinc | artillery fuse fragment | in water | 6/21/99 | Bob Neyland | Trench 1 |
| Hunhou 99-029 | wood | wood plank | treated | 6/21/99 | Brett Seymour | Trench 1 |
| Hunhou 99-030 | wood | wood fragment | treated | 6/21/99 | Brett Seymour | Trench 1 |
| Hunhou 99-031 | coal | lump | treated | 6/16/99 | Chris Arner | Trench 1 |
| Hunhou 99-032 | wood | object? | In PEG or f-d | 6/14/99 | Chris Arner | Trench 1 |
| Hunhou 99-033 | wood | sliver | in PEG or f-d | 6/22/99 | Claire Peachey | Trench 1 |
| Hunhou 99-034 | brass, rubber | tube | treated | 6/22/99 | Chris Arner | Trench 1 |
| Hunhou 99-035 | wood | wood plank with tenon | treated | 6/22/99 | Bob Neyland | Trench 1 |
| Hunhou 99-036 | wood | leg and plank | in PEG or f-d | 6/22/99 | Chris Arner | Trench 1 |
| Hunhou 99-037 | concretion | lumps, 2 | not to be treated | 6/22/99 | Dave Grant | Trench 1 |
| Hunhou 99-038 | iron | crowbar? | in NaOH | 6/22/99 | Claire Peachey | Trench 1 |
| Hunhou 99-039 | iron | concretion | treatment in progress | 6/22/99 | Chris Arner | Trench 1 |
| Hunhou 99-040 | bone, animal | worked rib | treated | 6/22/99 | Chris Arner | Trench 1 |
| Hunhou 99-041 | brass, wood | gun part | not treated | 6/22/99 | Chris Arner | Trench 1 |
| Hunhou 99-042 | brass, wood, iron | pistol | not treated | 6/22/99 | Bob Neyland | Trench 1 |
| Hunhou 99-043 | coal | lumps, 3 | treated | 6/22/99 | Brett Seymour | Trench 1 |
| Hunhou 99-044 | brass, iron?, organic? | concretion | in Na2CO3 | 6/22/99 | Chris Arner | Trench 1 |
| Hunhou 99-045 | wood | sample of scarphed timber | treated | 6/22/99 | Bob Neyland | Trench 1 |
| Hunhou 99-046 | slate | fragment | treated | 6/22/99 | Chris Arner | Trench 1 |
| Hunhou 99-047 | iron | concretion | not to be treated | 6/23/99 | Claire Peachey | Trench 2 |

| <u>FIELD NO.</u> | <u>MATERIAL</u> | <u>OBJECT</u> | <u>STATUS</u> | <u>DATE RECOVERED</u> | <u>RECOVERED BY</u> | <u>LOCATION</u> |
|------------------|---------------------|----------------------|------------------------------------|-----------------------|---------------------|-----------------|
| Hunhou 99-048 | coal | lump | treated | 6/23/99 | Claire Peachey | Trench 2 |
| Hunhou 99-049 | wood | wood (object?) | treated | 6/23/99 | David Whall | Trench 2 |
| Hunhou 99-050 | concretion | natural | not to be treated | 6/24/99 | David Whall | Trench 2 |
| Hunhou 99-051 | coal | lump | treated | 6/24/99 | David Whall | Trench 2 |
| Hunhou 99-052 | lead | sheet | not treated | 6/24/99 | Dave Conlin | Trench 2 |
| Hunhou 99-053 | leather | shoe sole | treatment in progress | 6/24/99 | Brett Seymour | Trench 2 |
| Hunhou 99-054 | leather | shoe | 1 dry, 1 in PEG | 6/25/99 | Carl Naylor | Trench 2 |
| Hunhou 99-055 | leather | shoe sole | treatment in progress | 6/25/99 | Bob Neyland | Trench 2 |
| Hunhou 99-056 | leather | shoe soles, 2 | treatment in progress | 6/25/99 | Bob Neyland | Trench 2 |
| Hunhou 99-057 | leather | heel | treatment in progress | 6/25/99 | Brett Seymour | Trench 2 |
| Hunhou 99-058 | leather | sole and upper parts | treatment in progress | 6/25/99 | Bob Neyland | Trench 2 |
| Hunhou 99-059 | leather | upper fragment | treatment inactive | 6/25/99 | Bob Neyland | Trench 2 |
| Hunhou 99-060 | iron | concretion | in Na ₂ CO ₃ | 6/25/99 | Chris Amer | Trench 2 |
| Hunhou 99-061 | bronze | bar | treated | 6/25/99 | Bob Neyland | Trench 2 |
| Hunhou 99-062 | brass | gun part | not treated | 6/25/99 | Bob Neyland | Trench 3 |
| Hunhou 99-063 | encrustation, fiber | rope frag? | not treated | 6/25/99 | Bob Neyland | Trench 2 |
| Hunhou 99-064 | zinc | artillery fuse | in water | 6/25/99 | Bob Neyland | Trench 2 |
| Hunhou 99-065 | glass | flat glass fragment | treated | 6/25/99 | Bob Neyland | Trench 2 |
| Hunhou 99-066 | iron | bar, 2 pieces | in Charleston | 6/25/99 | David Whall | Trench 2 |
| Hunhou 99-067 | bronze | pivot | treatment inactive | 6/25/99 | Chris Amer | Trench 2 |
| Hunhou 99-068 | wood | squared piece | in PEG for 1-d | 6/25/99 | Chris Amer | Trench 2 |
| Hunhou 99-069 | copper alloy | drift pin | treatment inactive | 6/25/99 | Chris Amer | Trench 2 |
| Hunhou 99-070 | iron | concretion | in Charleston | 6/25/99 | Chris Amer | Trench 2 |
| Hunhou 99-071 | iron | concretion | in Charleston | 6/25/99 | Chris Amer | Trench 2 |

| FIELD NO. | MATERIAL | OBJECT | STATUS | DATE RECOVERED | RECOVERED BY | LOCATION |
|---------------|------------------------|-----------------------|------------------------|----------------|----------------|-------------------------|
| Hunhou 99-072 | iron | concretion | in Charleston | 6/25/99 | Dave Conlin | Trench 2 |
| Hunhou 99-073 | wood, coal | fragments, 2 | treated | 6/25/99 | Chris Amer | Trench 2 |
| Hunhou 99-074 | ceramic | tureen? base fragment | treated | 6/25/99 | Chris Amer | Trench 2 |
| Hunhou 99-075 | ceramic | jar rim fragment | treated | 6/25/99 | Brett Seymour | Trench 2 |
| Hunhou 99-076 | wood, graphite?, lead? | pencil, half | not treated | 6/25/99 | Chris Amer | Trench 2 |
| Hunhou 99-077 | enerustations | 3 pieces | treated | 6/25/99 | Bob Neyland | Trench 2 |
| Hunhou 99-078 | iron | concretion (shot?) | In NaOH | 6/25/99 | Bob Neyland | Trench 2 |
| Hunhou 99-079 | coal | lump | treated | 7/3/99 | Bob Neyland | Trench 3 |
| Hunhou 99-080 | copper alloy | drift pin | treatment inactive | 7/6/99 | Mark Ragan | Trench 3 |
| Hunhou 99-081 | iron | concretion | in Charleston | 7/6/99 | Claire Peachey | Trench 3 |
| Hunhou 99-082 | lead | weight, teardrop | treated | 7/6/99 | Claire Peachey | Trench 3 |
| Hunhou 99-083 | copper alloy | drift pin | treated | 7/7/99 | Carl Naylor | Trench 3 |
| Hunhou 99-084 | iron | concretion | in Charleston | 7/7/99 | Mark Ragan | Trench 3 |
| Hunhou 99-085 | copper alloy | drift pin | treated | 7/7/99 | Mark Ragan | Trench 3 |
| Hunhou 99-086 | iron | chain concretion | in Na2CO3 | 7/7/99 | Mark Ragan | Trench 3 |
| Hunhou 99-087 | copper alloy | drift pin | treated | 7/7/99 | Bob Neyland | Trench 3 |
| Hunhou 99-088 | iron? | concretion | in Charleston | 7/7/99 | Bob Neyland | Trench 3 |
| Hunhou 99-089 | iron | concretion | in Charleston | 7/7/99 | Bob Neyland | Trench 3 |
| Hunhou 99-090 | copper alloy | chain links | treated | 7/7/99 | Dave Conlin | Trench 3 |
| Hunhou 99-091 | copper alloy | drift pin | treatment inactive | 7/8/99 | Mark Ragan | Trench 3 |
| Hunhou 99-092 | coal | lumps, 5 | treated | 7/8/99 | Jim Spirek | Trench 3 |
| Hunhou 99-093 | copper alloy | lack | treated | 7/8/99 | Jim Spirek | Trench 3 |
| Hunhou 99-094 | copper | sheeting, 3 pieces | treated | 7/8/99 | Dave Conlin | Trench 3 |
| Hunhou 99-095 | carbonate | wormrock | perm transfer Mei Bell | 6/9/99 | Dave Conlin | 3 rd anomaly |

| FIELD NO. | MATERIAL | OBJECT | STATUS | DATE RECOVERED | RECOVERED BY | LOCATION |
|---------------|-----------------|---------|--------------------|----------------|--------------|------------|
| Hunhou 99-096 | sediment sample | Hous 1 | perm transfer USGS | 5/25/99 | Dave Conlin | Housatonic |
| Hunhou 99-097 | sediment sample | Hous 2 | perm transfer USGS | 5/25/99 | Dave Conlin | Housatonic |
| Hunhou 99-098 | sediment sample | Hous 3 | perm transfer USGS | 5/25/99 | Dave Conlin | Housatonic |
| Hunhou 99-099 | sediment sample | HUPB 1A | perm transfer SCI | 5/26/99 | Dave Conlin | Hunley |
| Hunhou 99-100 | sediment sample | HUSB 1A | perm transfer SCI | 5/26/99 | Dave Conlin | Hunley |
| Hunhou 99-101 | sediment sample | HUSB 1B | perm transfer USGA | 5/26/99 | Dave Conlin | Hunley |

APPENDIX B

Letter from Melvin Bell

South Carolina Department of Natural Resources



Paul A. Sandifer, Ph.D.
Director
John V. Miglaresc
Deputy Director for
Marine Resources

March 1, 2001

Dr. David Conlin:
National Park Service
Submerged Resources Center
2968 Rodeo Park Drive West
Sante Fe, New Mexico 87505

Dear Dave:

Enclosed is a written analysis prepared by Bob Martore of the sample of "worm rock" you provided from your work on the wreck of the USS Housatonic. Determining the date of origin of the colony itself is beyond our capability, but perhaps your best clue for a "no earlier than" date would come from the type of cable or line the colony developed around.

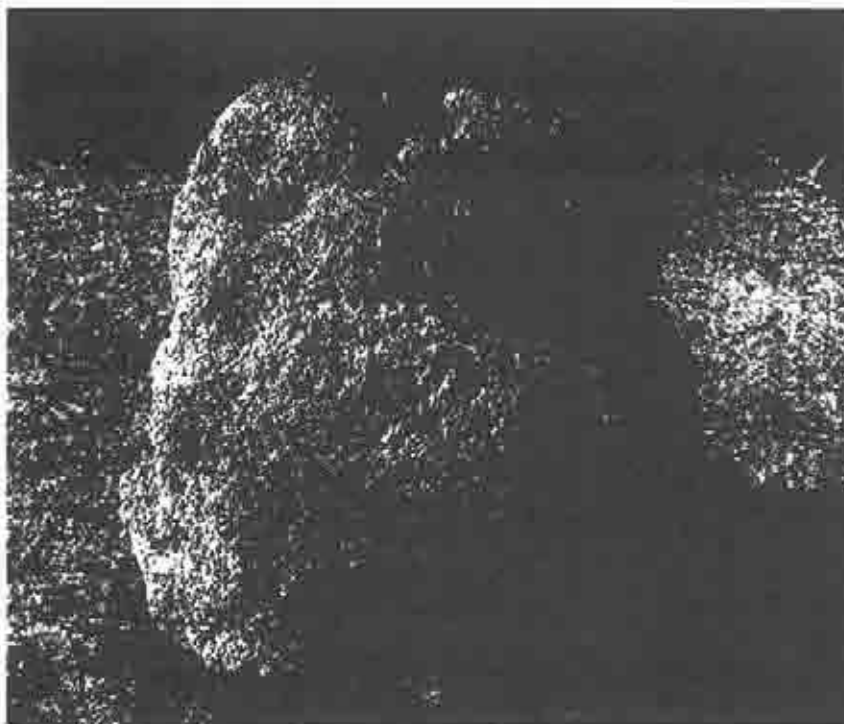
I have also enclosed a copy of a reference I recently came across which I think clearly explains the process of burial that occurred in the case of the Hunley. As I have mentioned before, we see this process occurring in varying degrees on almost all of our artificial reef materials along the coast. What Figure 3.1 does not show that we see routinely is the subsidence of the structure through the softer sand, mud and shell sediments until it reaches a firmer layer of Pleistocene marl. On larger sunken structures such as ships there can even be significant scouring into the marl, depending upon storm activity and intensity of water flow around the vessel. In the case of smaller structures we have observed, cutting into the marl is usually minimal and the infilling of softer sediments and eventual partial to full burial is much more common. Some cylindrical objects we have used in the past as reef materials (fuel tanks, culvert pipe, concrete-filled steel pipe) have completely buried in a matter of five to ten years. Significant burial of materials can be accelerated due to the occurrence of major storms.

Another aspect of the burial mechanism in Figure 3.1 not mentioned that we see on a regular basis is the very obvious change in sediment type immediately around the object scouring into the sea floor. Due to the hydrodynamic forces acting immediately around the structure, smaller particle sized materials are easily transported away, leaving an accumulation of much larger sized materials. In elongated structures such as boats, barges and ships, we consistently see large accumulations of shell at both ends where scouring is typically most pronounced.

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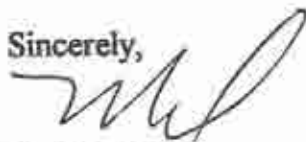
Temporary, rock-like reef structures, sometimes referred to as "worm rock" are built by tube building marine worms of the family Sabellariidae. These moderate sized polychaetes reach only about 50 millimeters in length, yet colonies composed of millions of individuals can construct honeycomb-like aggregations several feet across and up to two feet thick. They are found from near-shore, intertidal areas out to substantial depths and generally require hard substrate to begin a colony. They are thought to favor areas of high turbidity where wave motion provides a source of sand for tube building. Individual worms build sand grain tubes in which they live by bonding sand grains and shell fragments together with a protein cement secreted as mucus. As the worms grow, they add larger and larger fragments to their tubes. Individuals within a colony build their tubes on top of each other creating the aggregation. After spawning, larvae settle out onto the colony as well so that it continues to grow for several generations. Additional larvae may drift through the plankton and settle elsewhere to form new colonies. In this manner colonies can form and grow quickly. They undergo rapid growth in summer months but slow or stop in winter. Even the largest colonies are thought to persist for only two to three years then, as worms die off, the colony begins to deteriorate.

The sample in question measured 14 inches high by 12 inches wide (355 mm X 300 mm). This level of growth could have been achieved within one year's time. The colony was formed around a length of steel cable which ran completely through the entire aggregation. The central position of the cable and the symmetrical shape of the colony suggest that the cable was probably the initial attachment point for the worms with successive tubes aggregating around it. Orientation of the colony and cable indicate that the cable was probably buoyed and upright at the time of colonization. Although no live worms were found in the colony, lack of deterioration suggests that it was a relatively recent aggregate. Complete burial in the sand or mud could have preserved the colony for a short time but burial for extended periods generally results in a much greater degree of discoloration to the colony.

From over 20 years of personal experience in closely observing sunken structures in the ocean (many only a few miles from the Hunley site), I am convinced that the burial process described in the enclosed figure is an accurate portrail of what occurred to the sunken remains of the Hunley. The observations of the positions and conditions of calcareous remains of the sessile invertebrate organisms (primarily colonies of the star coral *Astrangia danae*) both Bob Martore and I made during dives on the Hunley in 1996 and again in 2000 also seem to confirm this conclusion. During our dive on May 26, 2000, when visibility for brief moments was noticeably better than our 1996 dive, we did detect a slight variation in the color of some of the coral colonies on the top of the aft hatch. Some of the coral on this part of the vessel was lighter in appearance (and perhaps younger) than the darker gray specimens found previously. This might suggest that during the burial process the Hunley's aft hatch may have been the last portion of the vessel to remain exposed above the sand bottom. Also, a few of the coral colonies seen during the most recent dive may have been from a different hard coral species, ivory bush coral (*Oculina arbuscula*), commonly encountered on many natural and man made reefs along the South Carolina coast. Since no samples of coral were collected during this dive this could not be confirmed.

I hope this information is of use to you in your further evaluation of both the Hunley and Housatonic. Bob and I thoroughly enjoyed working with you and the other team members on this project over the past few years. If we can be of any further assistance please let us know.

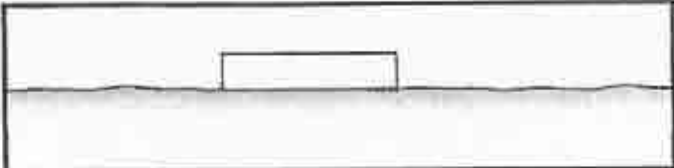
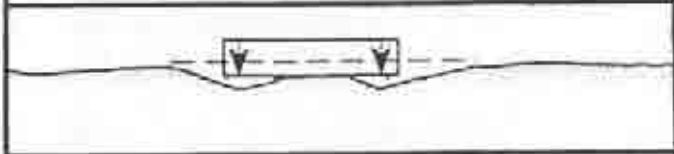
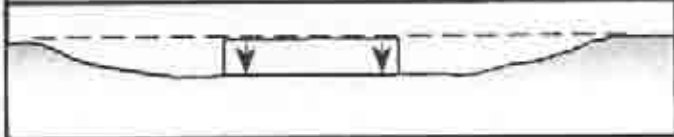
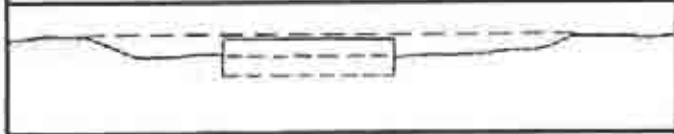

Sincerely,



Melvin Bell
Supervisor,
Finfish Management Section

cc: J. Miglarese
D. Cupka
B. Martore

Enclosures

| | |
|---|--|
|  | Position at Initial Placement |
|  | Scour Begins, Footing Is Undermined and Moves Down into the Hole |
|  | Scour Hole Depth Exceeds Object Height and... |
|  | Infilling Begins |
|  | Infilling Covers Object |

Possible Burial Mechanism for Small Structures Subject to Scour (After Sheng 2000 and Tian 1994)

The following table shows the results of the regression analysis. The dependent variable is the natural logarithm of the number of employees. The independent variables are the natural logarithm of the number of sales, the natural logarithm of the number of assets, and the natural logarithm of the number of liabilities. The results show that the number of sales is positively related to the number of employees, while the number of assets and liabilities are negatively related.

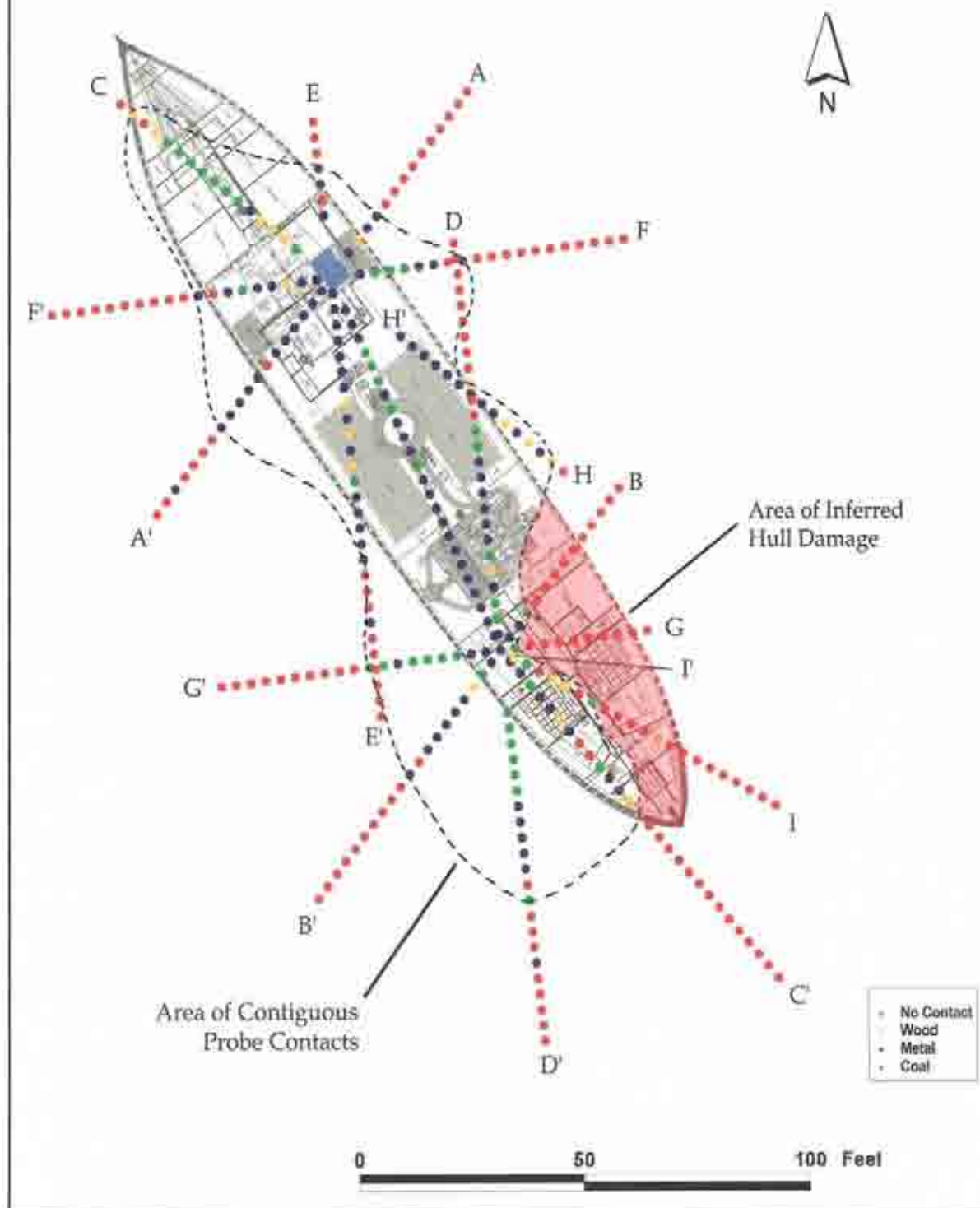
| Variable | Coefficient | Standard Error | t-statistic | p-value |
|-----------------|-------------|----------------|-------------|---------|
| ln(Sales) | 0.15 | 0.02 | 7.5 | < 0.001 |
| ln(Assets) | -0.08 | 0.02 | -4.0 | < 0.001 |
| ln(Liabilities) | -0.05 | 0.02 | -2.5 | 0.012 |
| Constant | 1.2 | 0.1 | 12.0 | < 0.001 |

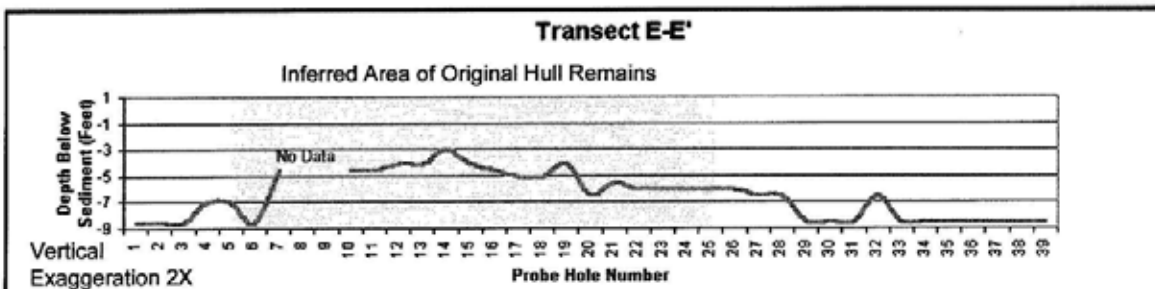
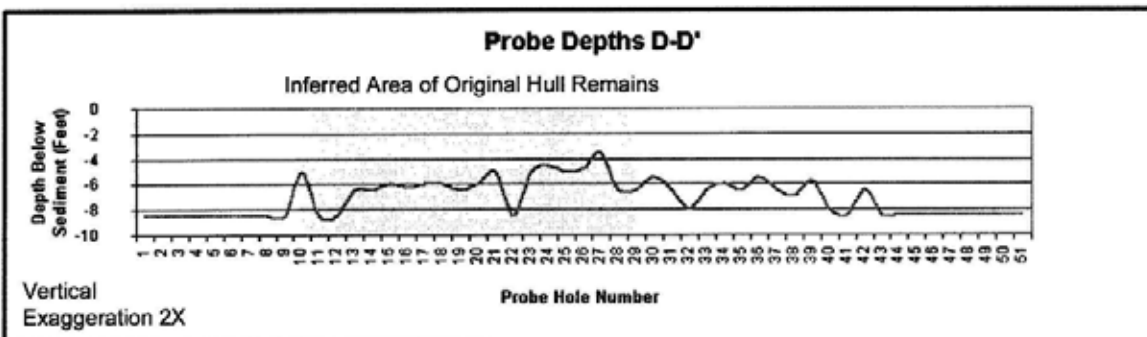
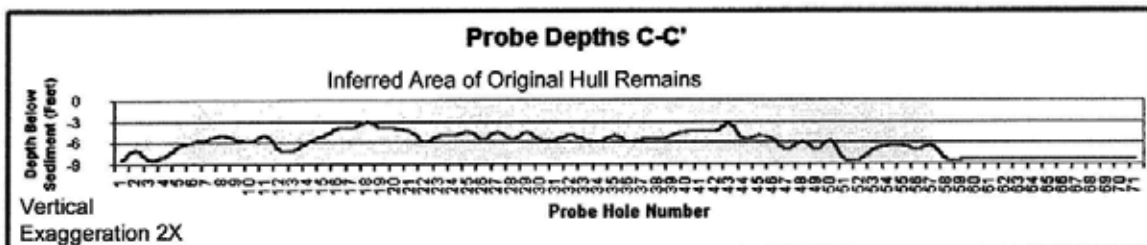
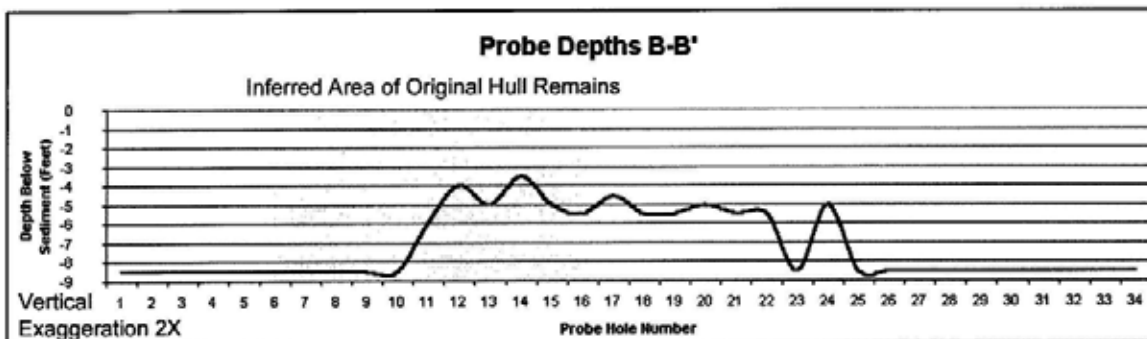
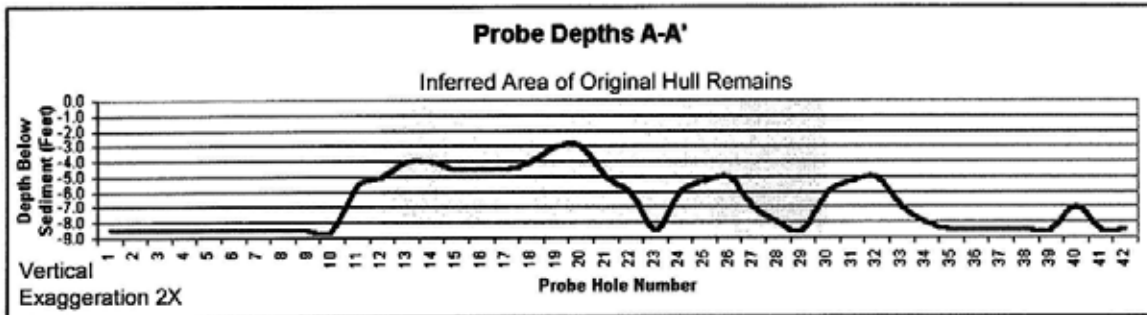
The regression equation is: $\ln(\text{Employees}) = 1.2 + 0.15 \ln(\text{Sales}) - 0.08 \ln(\text{Assets}) - 0.05 \ln(\text{Liabilities})$.

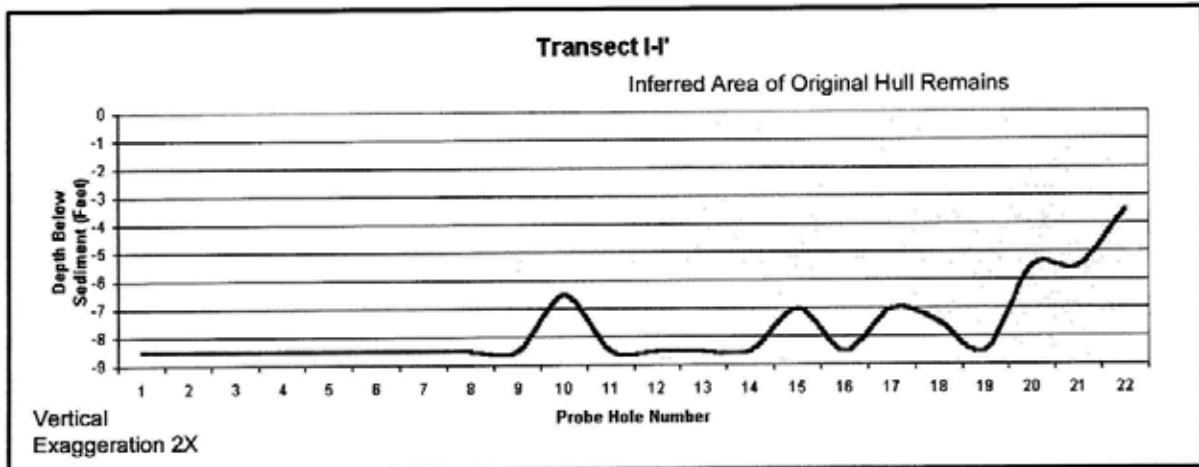
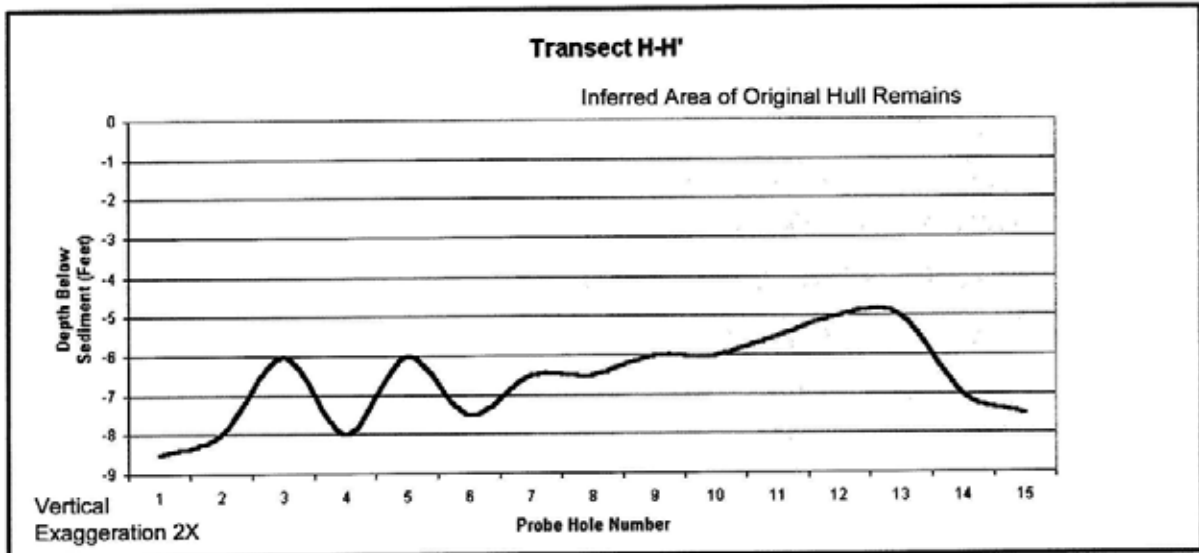
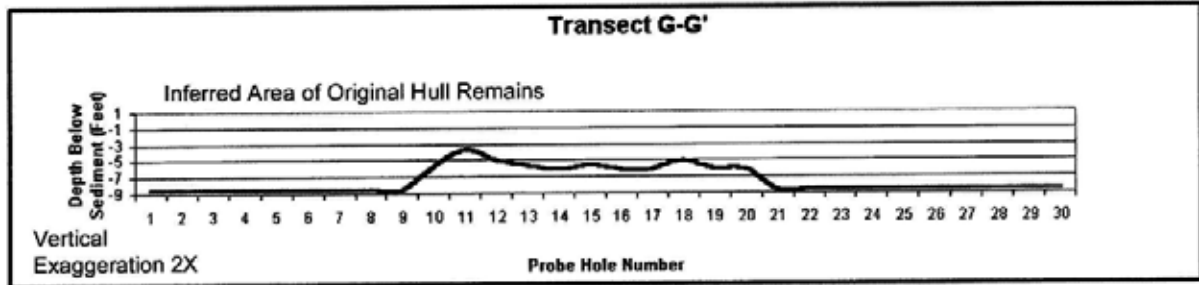
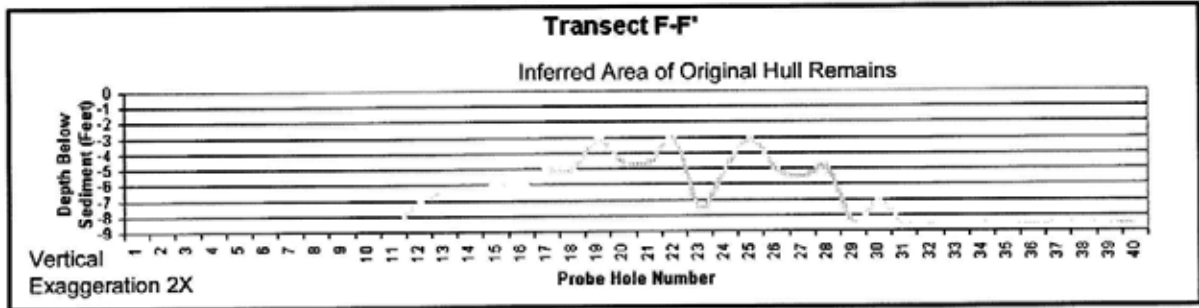
APPENDIX C

HOUSATONIC PROBE LINES

Housatonic Probe Lines







APPENDIX D

Geotechnical Soil Testing and Photographic Documentation

The Hunley Project

Charleston, South Carolina

Geotechnical Soil Testing & Photographic Documentation

SCI Project No. 99-879

PREPARED BY:

SOIL CONSULTANTS, INC.
ENGINEERS & GEOLOGISTS
P.O. Drawer 698, Charleston, S.C. 29402

SINCE 1951

| |
|-------------------------------|
| Construction Materials |
| Non Destructive |
| Geotechnical |
| Environmental |



SOIL CONSULTANTS, INC.
ENGINEERS & GEOLOGISTS
Since 1951

P.O. Drawer 698 • Charleston, South Carolina 29402 • 843/723-4539 • Fax 843/723-3648

September 8, 1999

Mr. Dave Conlin
Naval Historical Center/UA
805 Kidder Breese, WNY
Washington D.C. 20374-5060

Reference: The Hunley Project
Charleston, South Carolina

SCI Report 99-879

Dear Mr. Conlin:

Enclosed please find the test results requested for the above referenced project.

Four tube samples were delivered to our firm, which were obtained by others, in the vicinity of the Hunley submarine. Three tubes were selected by you for soils description and testing.

Each of the tubes selected was split vertically on each side, to facilitate continuous observation of each specimen. Photographs were taken and visual descriptions recorded to document the contents of each tube sample. Each tube sample was tested at consistent intervals, at four different depths across the length of each tube. Each soil interval was tested for Atterberg Limits, Unconfined Compression Test and Hydrometer/Sieve Grainsize Analysis. Moisture Contents were taken at the top middle and bottom portions of each tube in consistent locations.

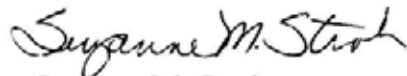


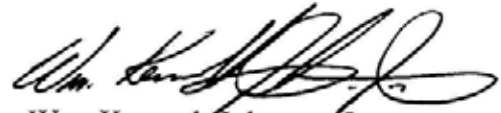
Mr. Dave Conlin
Page 2
September 8, 1999

If you have any questions regarding these tests, please don't hesitate to call our office.

We thank you for the opportunity to be of service to you on this project.

Sincerely,
SOIL CONSULTANTS, Inc.


Suzanne M. Stroh
Environmental Manager


Wm. Kenneth Johnson, Jr.
Vice President

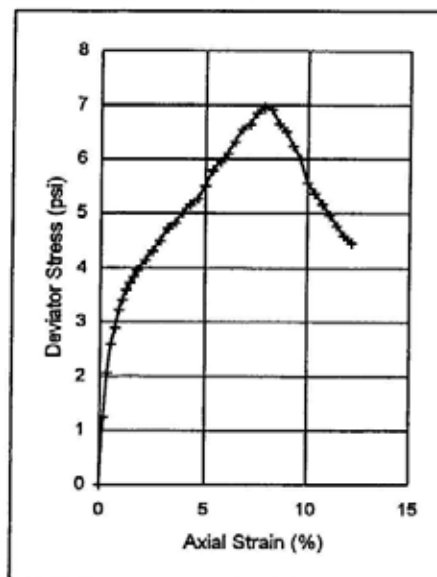
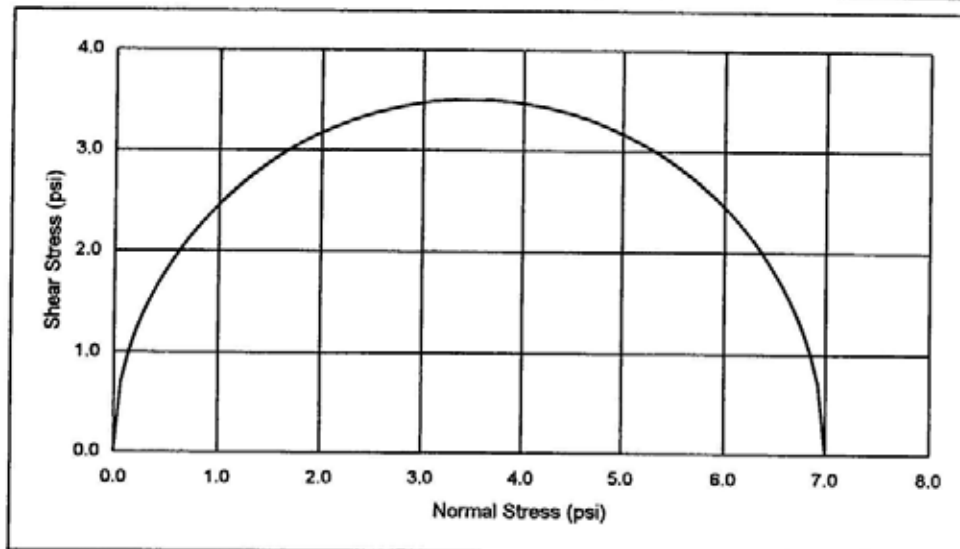
Cc: Mr. Bob Neyland (2 copies)

SCI
SOIL CONSULTANTS, INC.

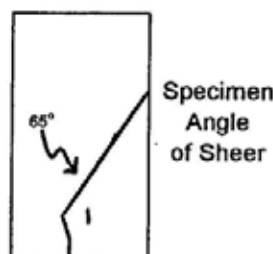
| | | | | | |
|---|--|--|--|--|--|
| Materials | | SOIL CONSULTANTS, INC. | | UNDISTURBED | |
| Testing Report | | P.O. Drawer 698, Charleston, S.C. 29402 | | SAMPLE CHARACTERISTICS | |
| Project And Location: The Hunley Project Charleston, South Carolina | | Sample No. 1A | | SCI Project No.: 99-879 | |
| Boring Location: HUSB | | Type of Sample: UD, Pushed | | Date: 7-20-99 | |
| <div style="display: flex; align-items: center;"> <div style="border-left: 1px solid black; border-right: 1px solid black; border-bottom: 1px solid black; width: 100%; height: 100%; position: relative;"> <div 1px="" ;="" black;"="" border-bottom:="" solid="" style="position: absolute; top: 0; left: 0; right: 0; height: 2.8"></div> <div 1px="" ;="" black;"="" border-right:="" solid="" style="position: absolute; top: 2.8; left: 0; right: 0; height: 210.5"></div> <div style="position: absolute; top: 210.5; left: 0; right: 0; height: 157; border-bottom: 1px solid black;"></div> <div style="position: absolute; top: 367; left: 0; right: 0; height: 152; border-bottom: 1px solid black;"></div> <div style="position: absolute; top: 519; left: 0; right: 0; height: 119; border-bottom: 1px solid black;"></div> <div style="position: absolute; top: 638; left: 0; right: 0; height: 86; border-bottom: 1px solid black;"></div> <div style="position: absolute; top: 724; left: 0; right: 0; height: 77; border-bottom: 1px solid black;"></div> <div style="position: absolute; top: 801; left: 0; right: 0; height: 46; border-bottom: 1px solid black;"></div> <div style="position: absolute; top: 847; left: 0; right: 0; height: 12; border-bottom: 1px solid black;"></div> </div> <div style="margin-left: 10px;"> <p>2.8"</p> <p>210.5"</p> <p>186"-191"</p> <p>157"</p> <p>152"</p> <p>138"-144"</p> <p>119"</p> <p>86"</p> <p>77"</p> <p>51"-57"</p> <p>46"</p> <p>12"-18"</p> </div> </div> | | Atterberg Limits Unconfined Compr. Hydrometer/Sieve Moisture: 27.0% | | Atterberg Limits: Non-Plastic Cohesion: 179 psf % Passing No. 200 Sieve: 11.9 | |
| | | Atterberg Limits Unconfined Compr. Hydrometer/Sieve Moisture: 23.8% | | Atterberg Limits: Liquid Limit 58; Plastic Limit 20; Plasticity Index 38 Cohesion: 476 psf % Passing No. 200 Sieve: 67.3 | |
| | | Atterberg Limits Unconfined Compr. Hydrometer/Sieve Moisture: 84.4% | | Atterberg Limits: Liquid Limit 29; Plastic Limit 17; Plasticity Index 12 Cohesion: 1075 psf % Passing No. 200 Sieve: 27.2 | |
| | | Atterberg Limits Unconfined Compr. Hydrometer/Sieve Moisture: 97.0% | | Atterberg Limits: Liquid Limit 97; Plastic Limit 39; Plasticity Index 58 Cohesion: 501 psf % Passing No. 200 Sieve: 97.0 | |
| | | Atterberg Limits Unconfined Compr. Hydrometer/Sieve Moisture: 27.0% | | Atterberg Limits: Non-Plastic Cohesion: 179 psf % Passing No. 200 Sieve: 11.9 | |
| | | Atterberg Limits Unconfined Compr. Hydrometer/Sieve Moisture: 23.8% | | Atterberg Limits: Liquid Limit 58; Plastic Limit 20; Plasticity Index 38 Cohesion: 476 psf % Passing No. 200 Sieve: 67.3 | |
| | | Atterberg Limits Unconfined Compr. Hydrometer/Sieve Moisture: 84.4% | | Atterberg Limits: Liquid Limit 29; Plastic Limit 17; Plasticity Index 12 Cohesion: 1075 psf % Passing No. 200 Sieve: 27.2 | |
| | | Atterberg Limits Unconfined Compr. Hydrometer/Sieve Moisture: 97.0% | | Atterberg Limits: Liquid Limit 97; Plastic Limit 39; Plasticity Index 58 Cohesion: 501 psf % Passing No. 200 Sieve: 97.0 | |
| | | Atterberg Limits Unconfined Compr. Hydrometer/Sieve Moisture: 27.0% | | Atterberg Limits: Non-Plastic Cohesion: 179 psf % Passing No. 200 Sieve: 11.9 | |
| | | Atterberg Limits Unconfined Compr. Hydrometer/Sieve Moisture: 23.8% | | Atterberg Limits: Liquid Limit 58; Plastic Limit 20; Plasticity Index 38 Cohesion: 476 psf % Passing No. 200 Sieve: 67.3 | |
| Atterberg Limits Unconfined Compr. Hydrometer/Sieve Moisture: 84.4% | | Atterberg Limits: Liquid Limit 29; Plastic Limit 17; Plasticity Index 12 Cohesion: 1075 psf % Passing No. 200 Sieve: 27.2 | | | |
| Atterberg Limits Unconfined Compr. Hydrometer/Sieve Moisture: 97.0% | | Atterberg Limits: Liquid Limit 97; Plastic Limit 39; Plasticity Index 58 Cohesion: 501 psf % Passing No. 200 Sieve: 97.0 | | | |

| | |
|------------------------------|--------------------|
| Texture | Clay, Sand & Shell |
| Visual Classification (USCS) | CH, SM, & SC |
| Color | Gray |
| Relative Moisture | Moist |
| Consistency | Semi-solid |
| Porosity or Structure | Banded |

| | | | | | |
|---|-------------------------------|--|--------------------------------|--|--|
| Materials Testing Report | | SOIL CONSULTANTS, INC. P.O. Drawer 698, Charleston, S.C. 29402 | | Unconfined Compression Test ASTM D 2166 | |
| Project And State: Hunley Project Charleston, S.C. | | | | Sample Location: HUSB | |
| Field Sample No. 1A | | Depth from tube bottom: 12"-18" | | Sample Description: Gray inorganic clay with slight sand and shell content. | |
| Type of Sample: Pushed | SCI Project: 99-879 | Cohesion: 501 psf | Calculations By: SMS | Date: July 21, 1999 | |
| | | | Approved By: AJM | | |



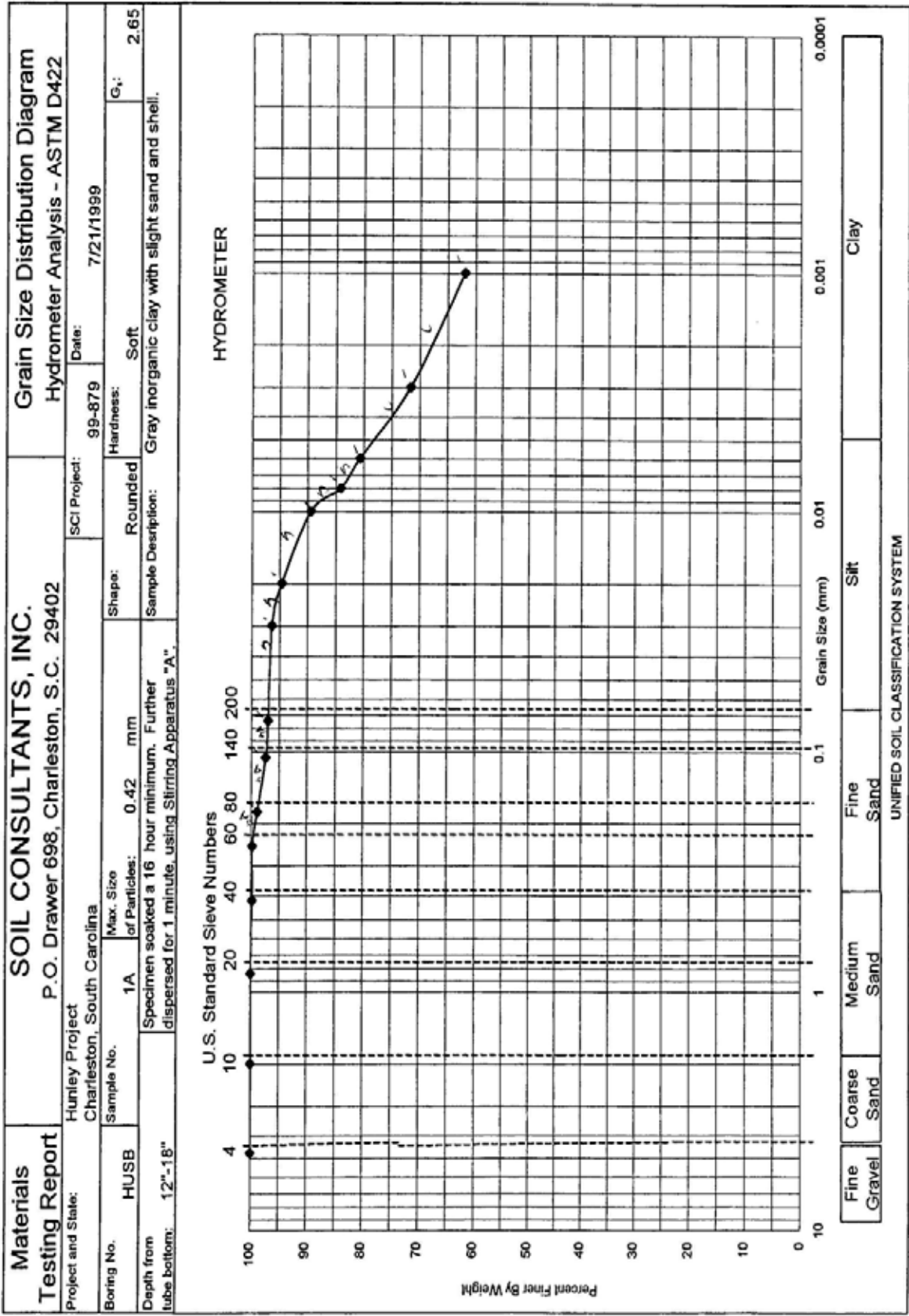
| Index Test Data | | | |
|-----------------|------|------------------|----|
| VUSCS: | CH | Liquid Limit | 97 |
| % Finer #200 | 97.0 | Plastic Limit | 39 |
| G(s) | 2.64 | Plasticity Index | 58 |



| Undisturbed Specimen Data | | | |
|--|---------|-------------------|-----|
| Height (inches): | 5.6 | Diameter (inches) | 2.8 |
| Method of Preparation: | Trimmed | L/D: | 2 |
| Average Rate of Strain to Failure: 0.056 inches/minute | | | |

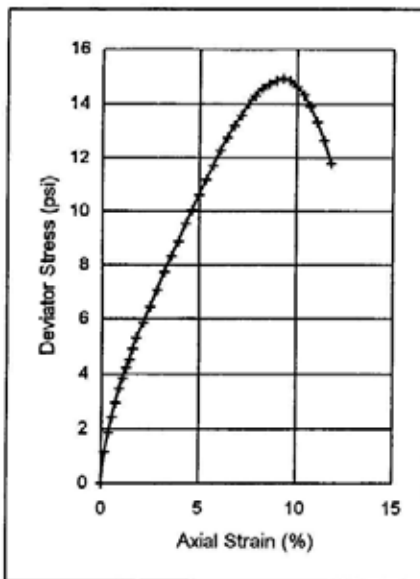
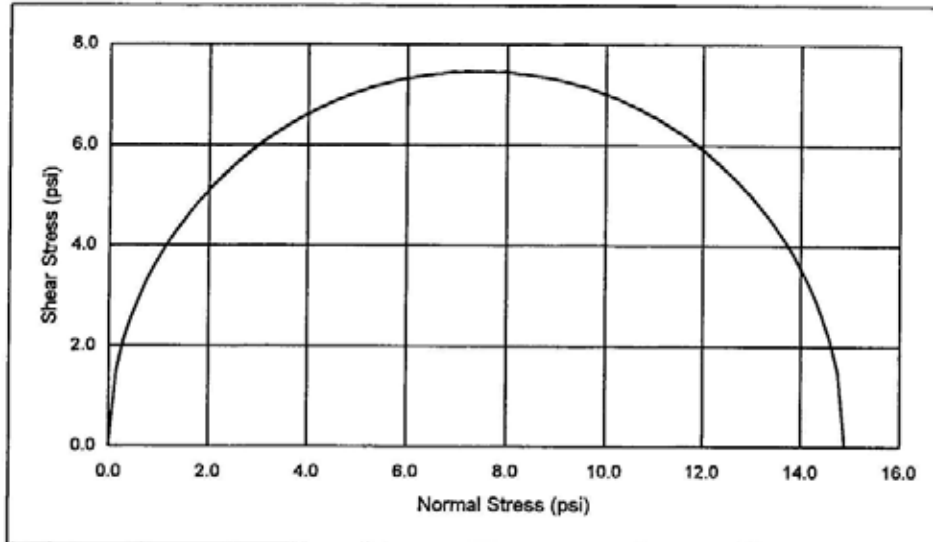
| Density | | Moisture Content | | | Time of Consolidation (hrs.) | Minor Principal Stress (psi) | Maximum Deviator Stress (psi) | Axial Strain at Failure (%) |
|-------------------|-------------------|------------------|-------------------------------------|---------------------------|------------------------------|------------------------------|-------------------------------|-----------------------------|
| Initial Wet (pcf) | Initial Dry (pcf) | Start of Test | Dep. of Saturation At Start of Test | End of Test Entire Sample | | | | |
| 94.9 | 51.6 | 82.6 | | 84.0 | | 7.0 | 7.9 | |
| | | | | | | | | |

Remarks:



Respectfully Submitted: *Eugene M. Stuch*

| | | | | | |
|---|------------------------|--|--|--|---------------------|
| Materials Testing Report | | SOIL CONSULTANTS, INC. P.O. Drawer 698, Charleston, S.C. 29402 | | Unconfined Compression Test ASTM D 2166 | |
| Project And State: Hunley Project Charleston, S.C. | | | Sample Location: HUSB | | |
| Field Sample No. 1A | | Depth from tube bottom: 51"-57" | Sample Description: Gray fine sand w/high inorganic clay and slight shell content. | | |
| Type of Sample: Pushed | SCI Project: 99-879 | Cohesion: 1075 psf | Calculations By: SMS | Date: July 19, 1999 | Approved By: AJM |



| Index Test Data | | |
|-----------------|------|---------------------|
| VUSCS: | SC | Liquid Limit 29 |
| % Finer #200 | 27.2 | Plastic Limit 17 |
| G(s) | 2.65 | Plasticity Index 12 |



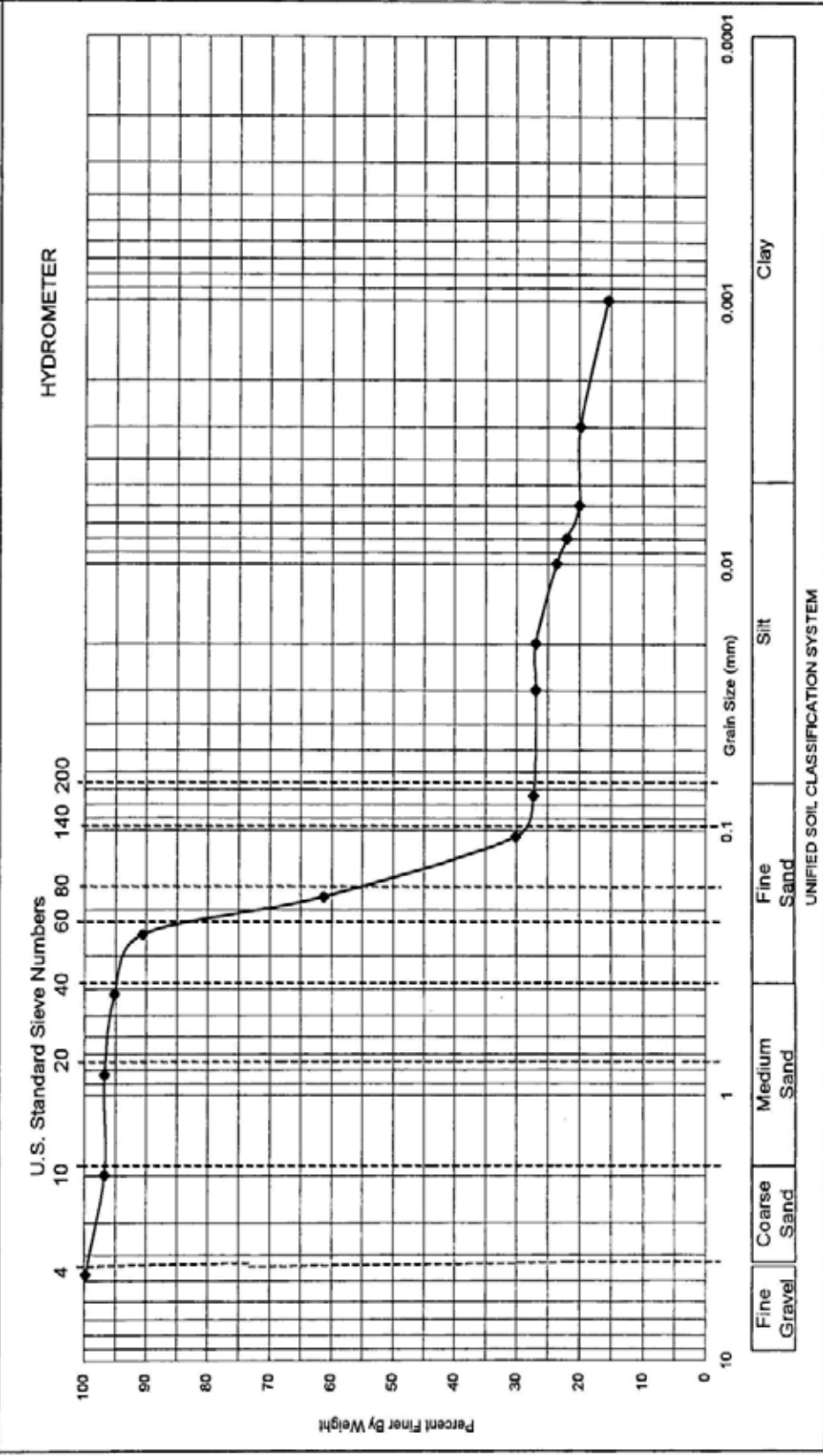
Specimen Angle of Shear

| Undisturbed Specimen Data | | | |
|------------------------------------|---------------------|-------------------|-----|
| Height (inches): | 5.6 | Diameter (inches) | 2.8 |
| Method of Preparation: | Trimmed | U/D: | 2 |
| Average Rate of Strain to Failure: | 0.056 inches/minute | | |

| Density | | Moisture Content | | | Time of Consolidation (hrs.) | Minor Principal Stress (psf) | Maximum Deviator Stress (psf) | Axial Strain at Failure (%) |
|-------------------|-------------------|------------------|-------------------------------------|---------------------------|------------------------------|------------------------------|-------------------------------|-----------------------------|
| Initial Wet (pcf) | Initial Dry (pcf) | Start of Test | Deg. of Saturation At Start of Test | End of Test Entire Sample | | | | |
| 125.6 | 102.4 | 22.3 | | 22.6 | | 14.9 | 9.29 | |
| | | | | | | | | |

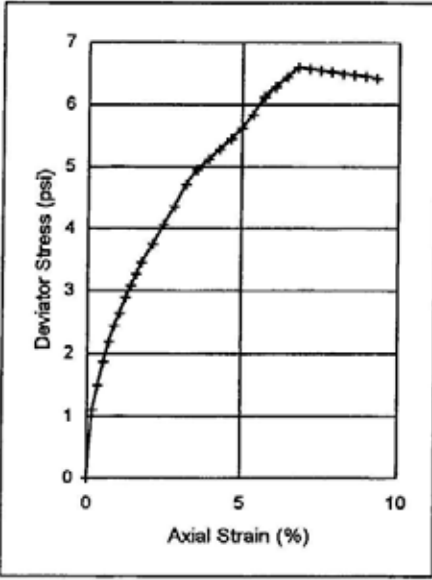
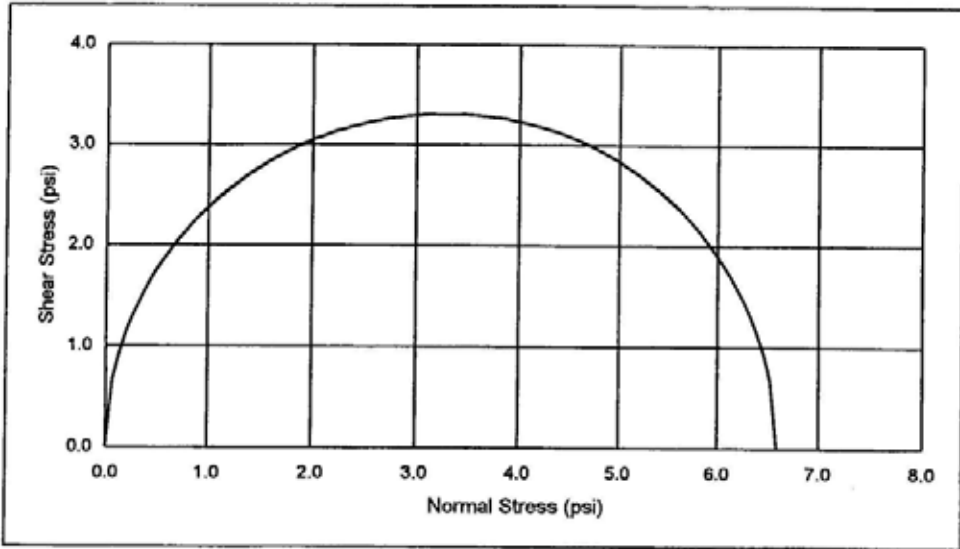
Remarks:

| | | | | | |
|---|---------|--|---------|--|---|
| Materials Testing Report | | SOIL CONSULTANTS, INC. | | Grain Size Distribution Diagram | |
| Project and State: Hunley Project Charleston, South Carolina | | P.O. Drawer 698, Charleston, S.C. 29402 | | Hydrometer Analysis - ASTM D422 | |
| Boring No.: | HUSB | Sample No.: | 1A | SCI Project: | 99-879 |
| Depth from tube bottom: | 51"-57" | Max. Size of Particles: | 4.76 mm | Shape: | Rounded |
| | | Specimen soaked a 16 hour minimum. Further dispersed for 1 minute, using Stirring Apparatus "A". | | Hardness: | Soft |
| | | | | Sample Description: | Gray fine sand with high clay and slight shell content. |
| | | | | Date: | 7/21/1999 |
| | | | | G _s : | 2.65 |

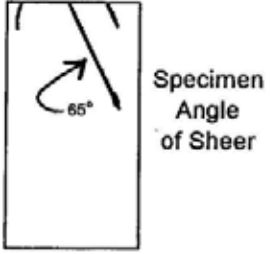


Respectfully Submitted: *Suzanne M. Stroh*

| | | | | | |
|---|------------------------|--|----------------------------------|---|------------------------|
| Materials Testing Report | | SOIL CONSULTANTS, INC. P.O. Drawer 698, Charleston, S.C. 29402 | | Unconfined Compression Test ASTM D 2166 | |
| Project And State: Hunley Project Charleston, S.C. | | | Sample Location: HUSB | | |
| Field Sample No. 1A | | Depth from tube bottom: 138"-144" | | Sample Description: Gray clay with slight to medium sand content. | |
| Type of Sample: Pushed | SCI Project: 99-879 | Cohesion: 476 psf | Calculations By: Approved By: | SMS AJM | Date: July 19, 1999 |



| Index Test Data | | | |
|-----------------|------|------------------|----|
| VUSCS: | CH | Liquid Limit | 58 |
| % Finer #200 | 67.3 | Plastic Limit | 20 |
| G(s) | 2.69 | Plasticity Index | 38 |

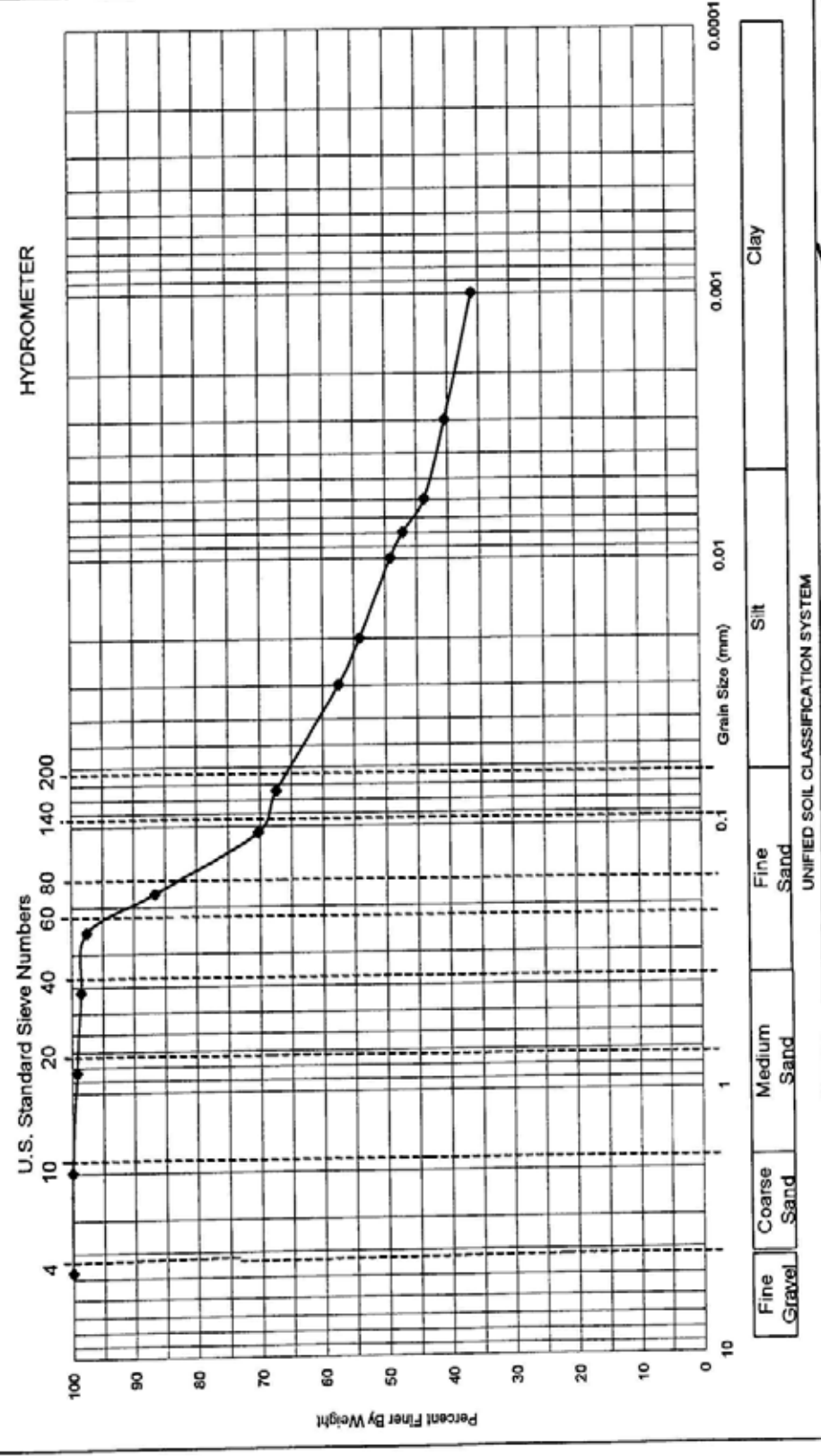


| Undisturbed Specimen Data | | | |
|------------------------------------|---------|---------------------|-----|
| Height (inches): | 5.6 | Diameter (inches) | 2.8 |
| Method of Preparation: | Trimmed | L/D: | 2 |
| Average Rate of Strain to Failure: | | 0.056 inches/minute | |

| Density | | Moisture Content | | | Time of Consolidation (hrs.) | Minor Principal Stress (psi) | Maximum Deviator Stress (psi) | Axial Strain at Failure (%) |
|-------------------|-------------------|------------------|-------------------------------------|---------------------------|------------------------------|------------------------------|-------------------------------|-----------------------------|
| Initial Wet (pcf) | Initial Dry (pcf) | Start of Test | Deg. of Saturation At Start of Test | End of Test Entire Sample | | | | |
| 108.3 | 70.7 | 53.3 | | 48.0 | | | 6.6 | 6.8 |
| | | | | | | | | |

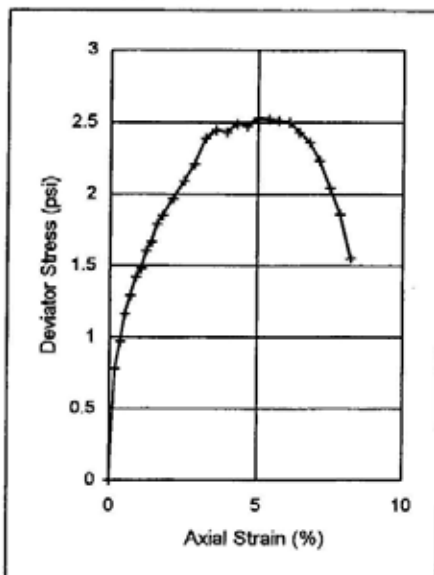
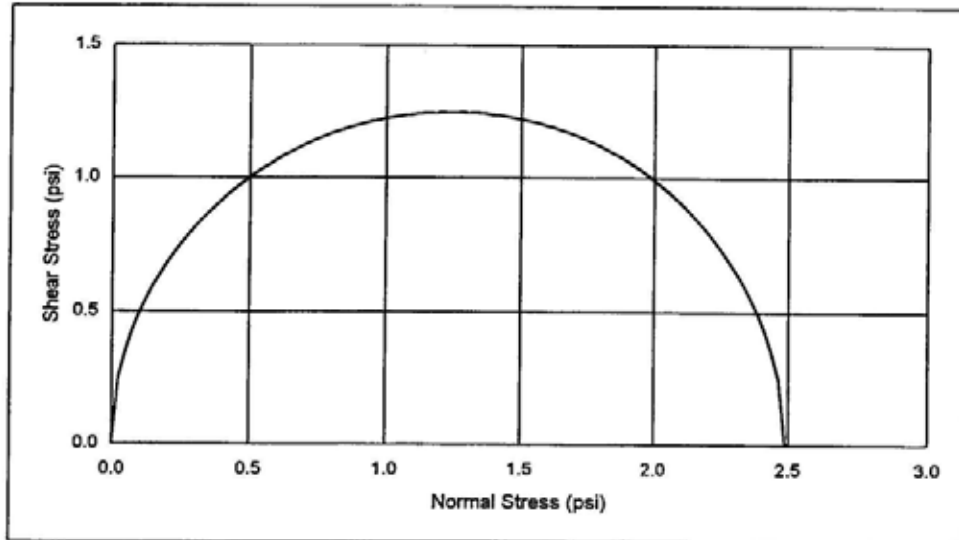
Remarks:

| | | | | | |
|---|------|--|----|---|---------|
| Materials Testing Report | | SOIL CONSULTANTS, INC. | | Grain Size Distribution Diagram | |
| Project and State: | | Hunley Project Charleston, South Carolina | | Hydrometer Analysis - ASTM D422 | |
| P.O. Drawer 698, Charleston, S.C. 29402 | | SCI Project: | | Date: 7/21/1999 | |
| Boring No. | HUSB | Sample No. | 1A | Max. Size of Particles: | 0.84 mm |
| Depth from tube bottom: 138"-144" | | Shape: | | Hardness: | Soft |
| | | Sample Description: | | G _s : 2.69 | |
| | | Specimen soaked a 16 hour minimum. Further dispersed for 1 minute, using Stirling Apparatus "A". | | Gray inorganic clay with slight to medium sand content. | |

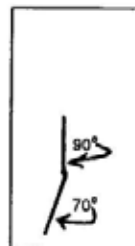


Respectfully Submitted: *Suzanne M. Stroh*

| | | | | | |
|---|--|--|--|--|--|
| Materials Testing Report | | SOIL CONSULTANTS, INC. P.O. Drawer 698, Charleston, S.C. 29402 | | Unconfined Compression Test ASTM D 2166 | |
| Project And State: Hunley Project Charleston, S.C. | | | | Sample Location: HUSB | |
| Field Sample No. 1A | | Depth from tube bottom: 186"-191" | | Sample Description: Gray fine sand with slight clay & shell w/ clay lenses in bottom 1/3 of specimen | |
| Type of Sample: Pushed | | SCI Project: 99-879 | | Cohesion: 179 psf | |
| | | Calculations By: Approved By: | | SMS AJM | |
| | | Date: | | July 19, 1999 | |



| Index Test Data | | | |
|-----------------|------|-------------------|-------------|
| VUSCS: | SM | Liquid Limit | Non-Plastic |
| % Finer #200 | 11.9 | Plastic Limit | Non-Plastic |
| G(s) | 2.64 | Plasticity Index: | Non-Plastic |



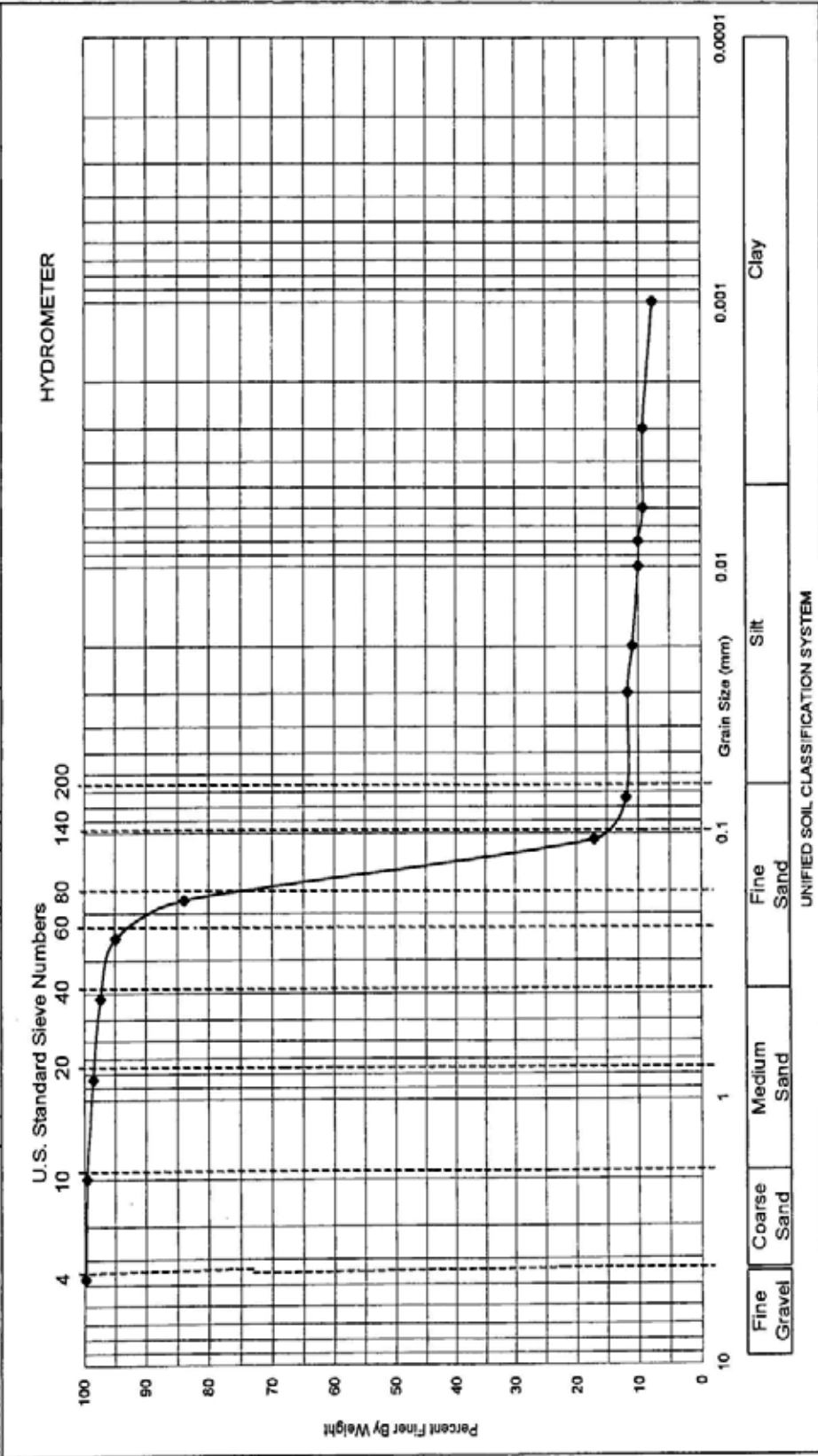
Specimen Angle of Shear

| Undisturbed Specimen Data | | | |
|------------------------------------|---------------------|-------------------|-----|
| Height (inches): | 5.6 | Diameter (inches) | 2.8 |
| Method of Preparation: | Trimmed | L/D: | 2 |
| Average Rate of Strain to Failure: | 0.056 inches/minute | | |

| Density | | Moisture Content | | | Time of Consolidation (hrs.) | Minor Principal Stress (psf) | Maximum Deviator Stress (psf) | Axial Strain at Failure (%) |
|-------------------|-------------------|------------------|-------------------------------------|---------------------------|------------------------------|------------------------------|-------------------------------|-----------------------------|
| Initial Wet (pcf) | Initial Dry (pcf) | Start of Test | Deg. of Saturation At Start of Test | End of Test Entire Sample | | | | |
| 114.9 | 87.5 | 31.3 | | 31.3 | | 2.49 | 4.29 | |
| | | | | | | | | |

Remarks:

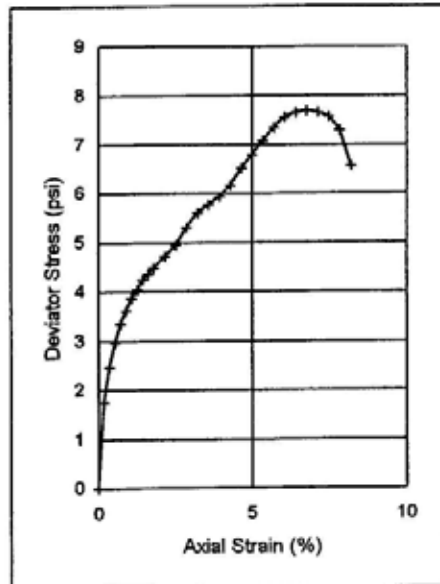
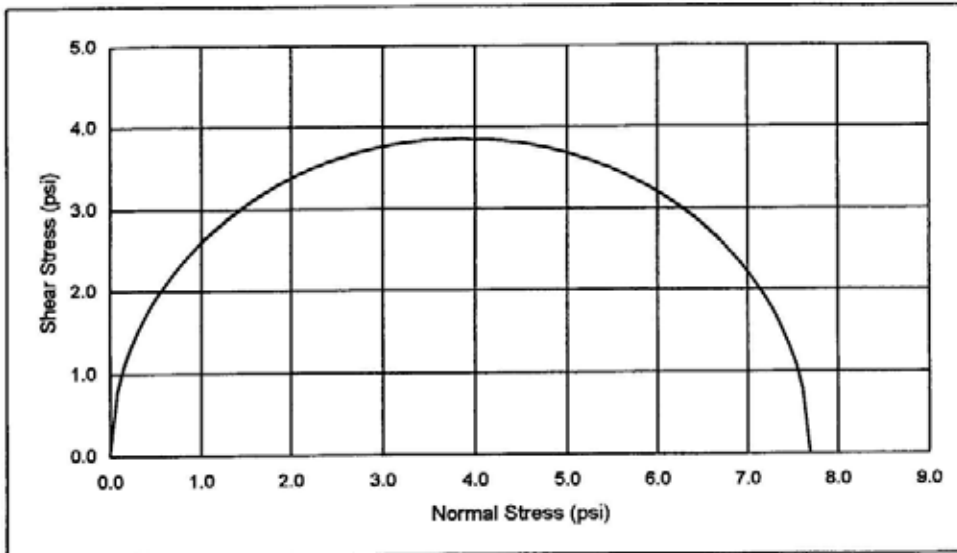
| | | | | | |
|---|-----------|---|---------|--|-----------------------|
| Materials Testing Report | | SOIL CONSULTANTS, INC. | | Grain Size Distribution Diagram | |
| Project and State: Hunley Project Charleston, South Carolina | | P.O. Drawer 698, Charleston, S.C. 29402 | | Hydrometer Analysis - ASTM D422 | |
| Boring No.: | HUSB | Sample No.: | 1A | SCI Project: | 99-879 |
| Depth from tube bottom: | 186"-191" | Max. Size of Particles: | 4.76 mm | Hardness: | 7/20/1999 |
| | | Shape: Rounded | | | |
| | | Sample Description: Gray fine sand with slight clay and high shell content. | | | |
| | | | | | G _s : 2.64 |



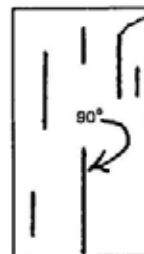
Respectfully Submitted: *Suzanne M. Stroh*

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|--|--|---|--|---|--|
| Materials Testing Report | | SOIL CONSULTANTS, INC. P.O. Drawer 698, Charleston, S.C. 29402 | | UNDISTURBED SAMPLE CHARACTERISTICS | |
| Project And Location: The Hunley Project Charleston, South Carolina | | Sample No.: 2A | | SCI Project No.: 99-879 | |
| Boring Location: HUPS | | Type of Sample: UD, Pushed | | Date: 7-20-99 | |
| 208.5" | | 2.8" | | Texture: Clay, Sand & Shell | |
| | | 208.5" | | Visual Classification (USCS): CH, SM, & SC | |
| | | Atterberg Limits | | Atterberg Limits: Non-Plastic | |
| | | Unconfined Compr. | | Cohesion: 136 psf | |
| | | Hydrometer/Sieve | | % Passing No. 200 Sieve: 13.9 | |
| | | Moisture: 30.8% | | Gray fine sand w/slight inorganic clay and medium to very high shell content. | |
| | | 186"-191" | | Atterberg Limits: Liquid Limit 64; Plastic Limit 21; Plasticity Index 43 | |
| | | Atterberg Limits | | Cohesion: 437 psf | |
| | | Unconfined Compr. | | % Passing No. 200 Sieve: 79.7 | |
| | | Hydrometer/Sieve | | Gray inorganic clay w/slight sand & shell. | |
| 119" | | Moisture: 50.3% | | Gray fine sand w/slight to medium inorganic clay and very high shell content. | |
| 93" | | Gray fine sand w/medium inorganic clay and high shell content. | | | |
| 80" | | Gray fine sand w/slight inorganic clay & very high shell. | | | |
| 70" | | Gray inorganic clay with slight sand and shell. | | | |
| Atterberg Limits | | Atterberg Limits: Non-Plastic | | | |
| Unconfined Compr. | | *Unconfined Compression was not attainable-sand sample broke apart | | | |
| Hydrometer/Sieve | | % Passing No. 200 Sieve: 16.6 | | | |
| 67" | | Gray fine sand with very slight inorganic clay and shell content. | | | |
| 43" | | Moisture: 81.9% | | Gray inorganic clay. | |
| Atterberg Limits | | Atterberg Limits: Liquid Limit 104; Plastic Limit 41; Plasticity Index 63 | | | |
| Unconfined Compr. | | Cohesion: 554 psf | | | |
| Hydrometer/Sieve | | % Passing No. 200 Sieve: 98.1 | | | |
| 12"-16" | | | | | |

| | | | | | |
|---|------------------------|--|-------------------------|--|--|
| Materials Testing Report | | SOIL CONSULTANTS, INC. P.O. Drawer 698, Charleston, S.C. 29402 | | Unconfined Compression Test ASTM D 2166 | |
| Project And State: Hunley Project Charleston, S.C. | | | | Sample Location: HUPS | |
| Field Sample No. 2A | | Depth from tube bottom: 12"-18" | | Sample Description: Gray inorganic clay. | |
| Type of Sample: Pushed | SCI Project: 99-879 | Cohesion: 554 psf | Calculations By: SMS | Date: July 16, 1999 | |
| | | | Approved By: AJM | | |



| Index Test Data | | | |
|-----------------|------|------------------|-----|
| VUSCS: | CH | Liquid Limit | 104 |
| % Finer #200 | 98.1 | Plastic Limit | 41 |
| G(s) | 2.63 | Plasticity Index | 63 |

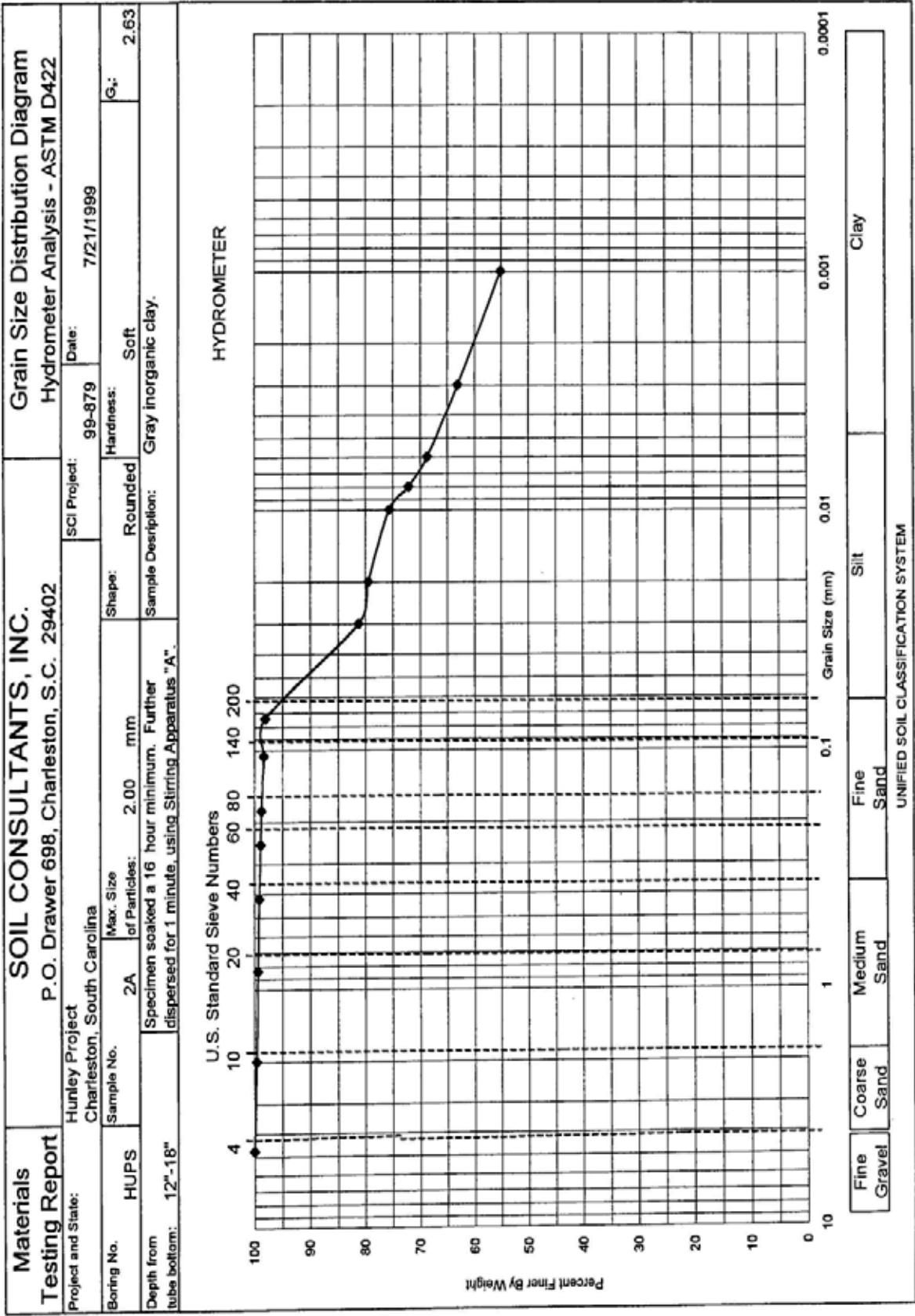


Specimen Angle of Shear

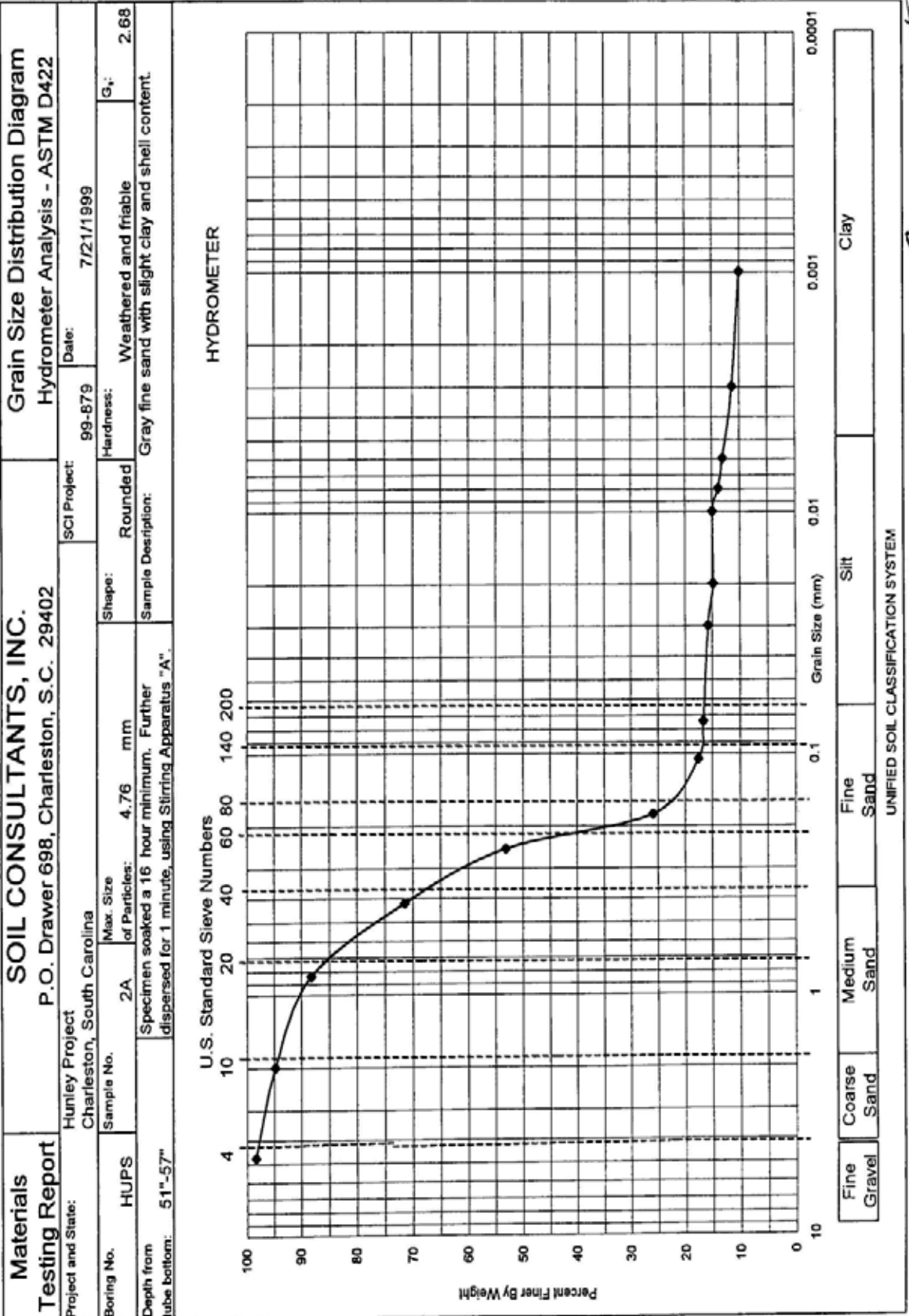
| Undisturbed Specimen Data | | | |
|------------------------------------|---------------------|-------------------|-----|
| Height (inches): | 5.6 | Diameter (inches) | 2.8 |
| Method of Preparation: | Trimmed | L/D: | 2 |
| Average Rate of Strain to Failure: | 0.056 inches/minute | | |

| Density | | Moisture Content | | | Time of Consolidation (hrs.) | Minor Principal Stress (psi) | Maximum Deviator Stress (psi) | Axial Strain at Failure (%) |
|-------------------|-------------------|------------------|-------------------------------------|---------------------------|------------------------------|------------------------------|-------------------------------|-----------------------------|
| Initial Wet (pcf) | Initial Dry (pcf) | Start of Test | Deg. of Saturation At Start of Test | End of Test Entire Sample | | | | |
| 91.4 | 47.8 | 87.8 | | 91.2 | | 7.7 | 6.8 | |
| | | | | | | | | |

Remarks:

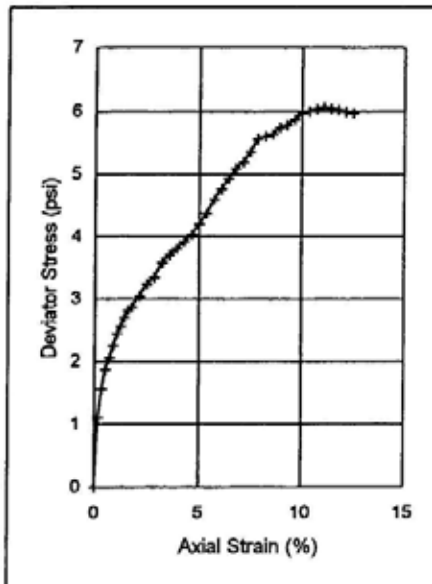
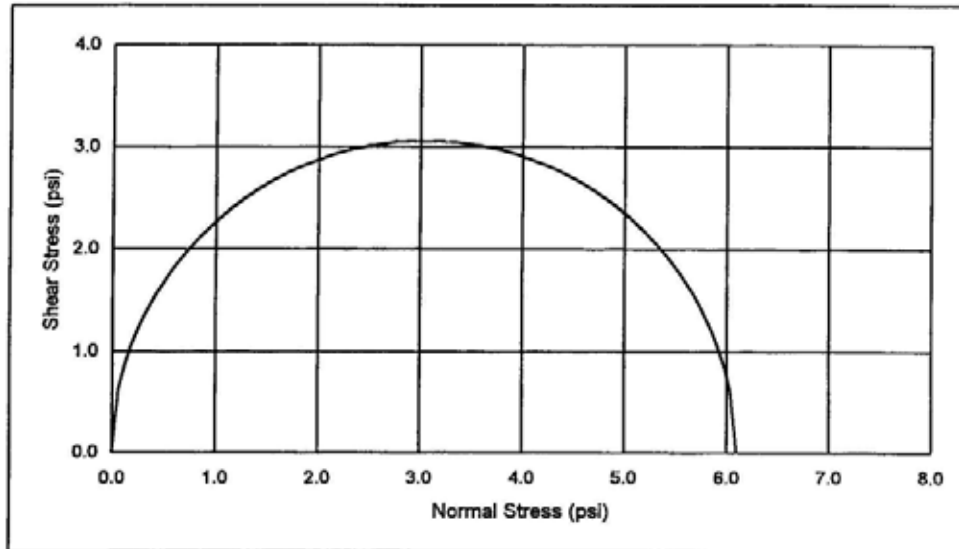


Respectfully Submitted: *Suzanne M. Stark*

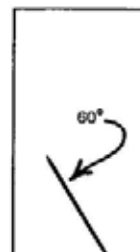


Respectfully Submitted: *Suzanne M. Stud*

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|---|------------------------|--|--|--|--|
| Materials Testing Report | | SOIL CONSULTANTS, INC. P.O. Drawer 698, Charleston, S.C. 29402 | | Unconfined Compression Test ASTM D 2166 | |
| Project And State: Hunley Project Charleston, S.C. | | | | Sample Location: HUPS | |
| Field Sample No. 2A | | Depth from tube bottom: 138"-144" | | Sample Description: Gray clay with slight sand and peat content. | |
| Type of Sample: Pushed | SCI Project: 99-879 | Cohesion: 437 psf | Calculations By: SMS Approved By: AJM | Date: July 19, 1999 | |



| Index Test Data | | | |
|-----------------|------|------------------|----|
| VUSCS: | CH | Liquid Limit | 64 |
| % Finer #200 | 79.7 | Plastic Limit | 21 |
| G(s) | 2.73 | Plasticity Index | 43 |



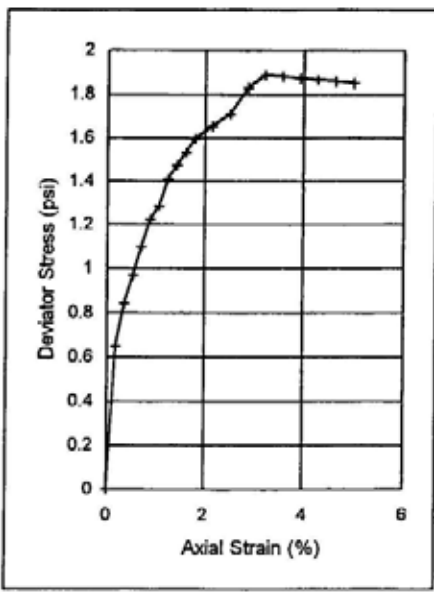
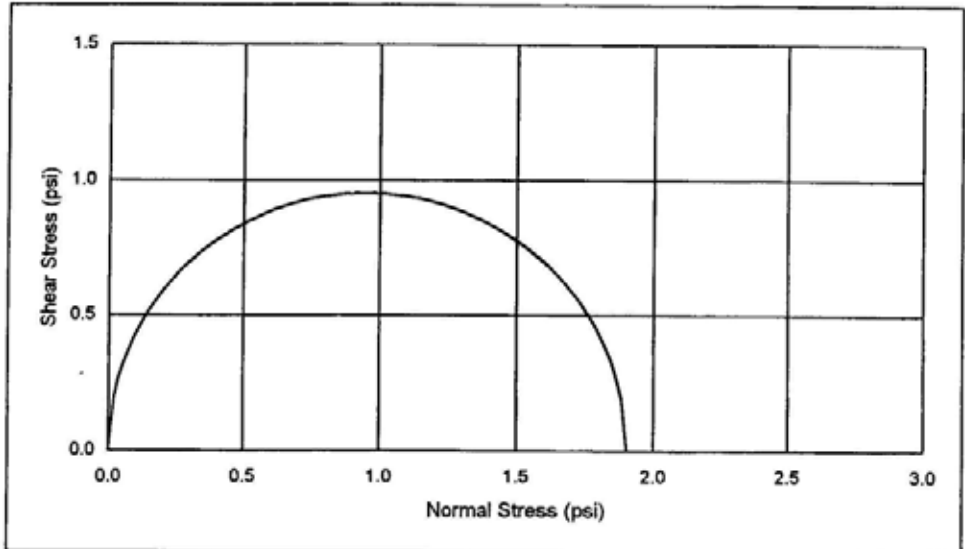
Specimen Angle of Shear

| Undisturbed Specimen Data | | | |
|------------------------------------|---------|---------------------|-----|
| Height (inches): | 5.6 | Diameter (inches) | 2.8 |
| Method of Preparation: | Trimmed | L/D: | 2 |
| Average Rate of Strain to Failure: | | 0.056 inches/minute | |

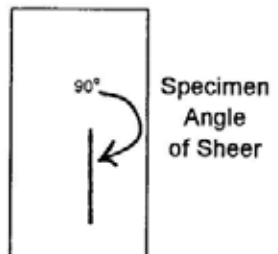
| Density | | Moisture Content | | | Time of Consolidation (hrs.) | Minor Principal Stress (psi) | Maximum Deviator Stress (psi) | Axial Strain at Failure (%) |
|-------------------|-------------------|------------------|-------------------------------------|---------------------------|------------------------------|------------------------------|-------------------------------|-----------------------------|
| Initial Wet (pcf) | Initial Dry (pcf) | Start of Test | Deg. of Saturation At Start of Test | End of Test Entire Sample | | | | |
| 104.9 | 71.1 | 44.2 | | 47.6 | | 6.1 | 11.07 | |
| | | | | | | | | |

Remarks:

| | | | | | |
|--|------------------------|--|-------------------------|---|--|
| Materials Testing Report | | SOIL CONSULTANTS, INC. P.O. Drawer 698, Charleston, S.C. 29402 | | Unconfined Compression Test ASTM D 2166 | |
| Project And Site: Hunley Project Charleston, S.C. | | | | Sample Location: HUPS | |
| Field Sample No. 2A | | Depth from tube bottom: 186"-191" | | Sample Description: Gray fine sand with slight clay & medium shell content. | |
| Type of Sample: Pushed | SCI Project: 99-879 | Cohesion: 136 psf | Calculations By: SMS | Date: July 19, 1999 | |
| | | | Approved By: AJM | | |



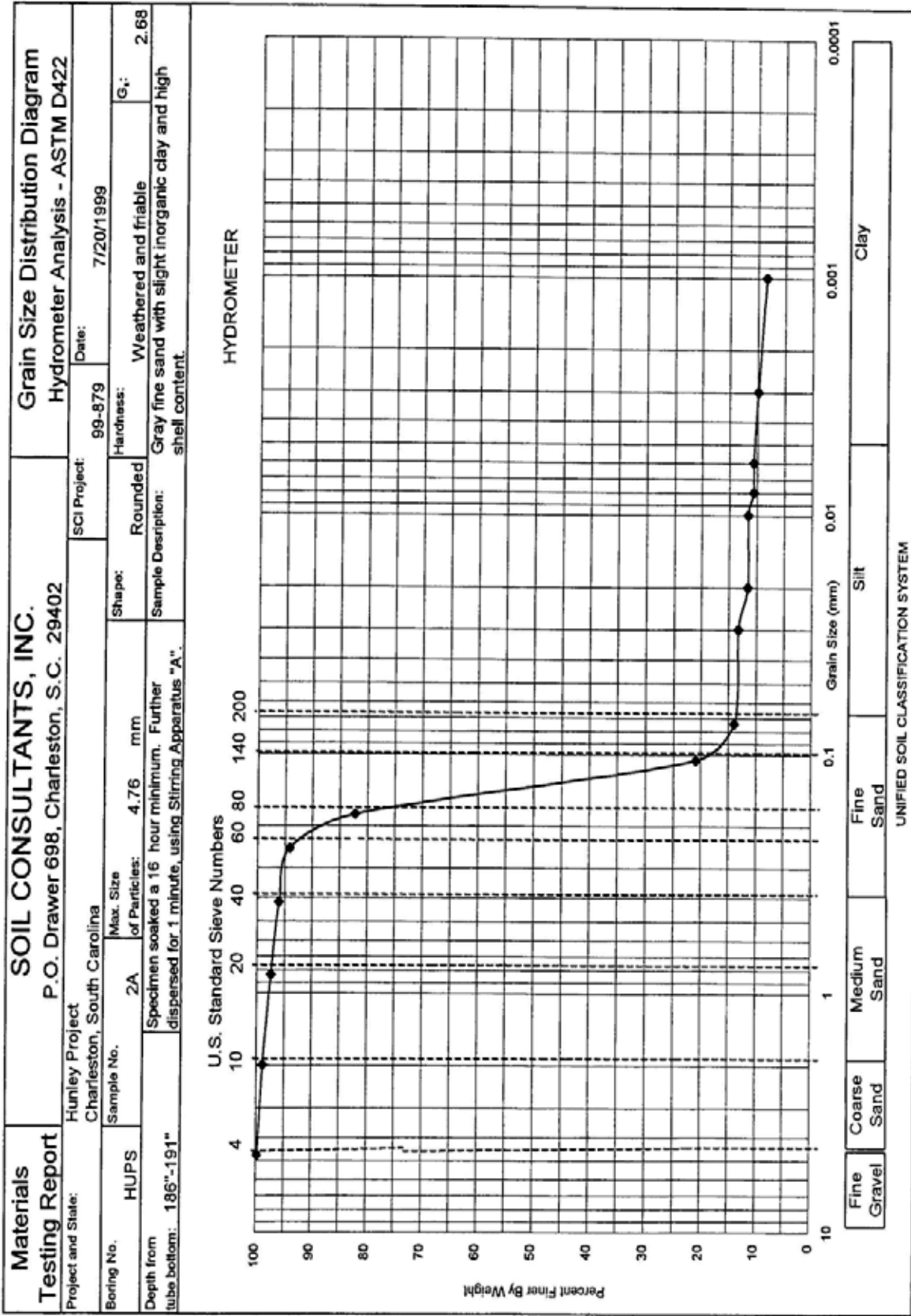
| Index Test Data | | | |
|-----------------|-------|-------------------|-------------|
| VUSCS: | SM-SC | Liquid Limit | Non-Plastic |
| % Finer #200 | 13.9 | Plastic Limit | Non-Plastic |
| G(s) | 2.68 | Plasticity Index: | Non-Plastic |



| Undisturbed Specimen Data | | | |
|------------------------------------|---------------------|-------------------|-----|
| Height (inches): | 5.6 | Diameter (inches) | 2.8 |
| Method of Preparation: | Trimmed | L/D: | 2 |
| Average Rate of Strain to Failure: | 0.056 inches/minute | | |

| Density | | Moisture Content | | | Time of Consolidation (hrs.) | Minor Principal Stress (psi) | Maximum Deviator Stress (psi) | Axial Strain at Failure (%) |
|-------------------|-------------------|------------------|-------------------------------------|---------------------------|------------------------------|------------------------------|-------------------------------|-----------------------------|
| Initial Wet (pcf) | Initial Dry (pcf) | Start of Test | Dep. of Saturation At Start of Test | End of Test Entire Sample | | | | |
| 112.4 | 82.6 | 31.6 | | 36.1 | | 1.9 | 3.22 | |
| | | | | | | | | |

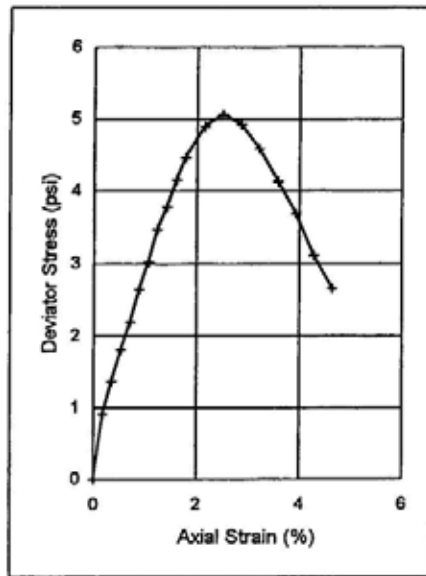
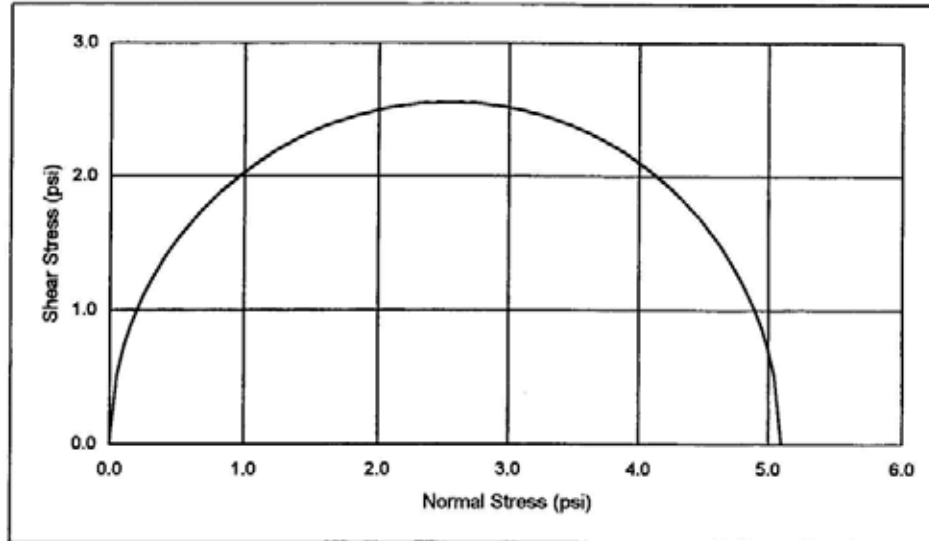
Remarks:



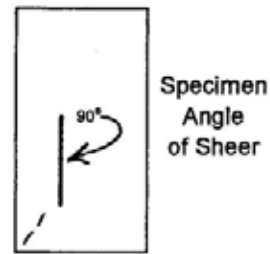
Respectfully Submitted: *Suzanne M. Stod*

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|---|----------------------|--|--------|---|-------------------|------------------|-----------------|-----------|------|------------------|-------------------|------------------|-----------|------|------|-----------------|------|------------------|-------------------|------------------|---------|-----|-----------------|-----|-------|-----|------------------|-------------------|------------------|-------|---------|--|--|---|--|---------|--------------------|------------------------------|--------------|-------|------|-------------------|-------|-------------|------------|-----------------------|--------|
| Materials Testing Report | | SOIL CONSULTANTS, INC. P.O. Drawer 698, Charleston, S.C. 29402 | | UNDISTURBED SAMPLE CHARACTERISTICS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Project And Location: The Hunley Project Charleston, South Carolina | | SCI Project No.: 99-879 | | Type of Sample: UD, Pushed | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Boring Location: HUPB | Sample No. 3A | | | Date: 7-20-99 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg); margin-right: 10px;">210.5"</div> <div style="border: 1px solid black; padding: 5px;"> <table border="1"> <tr><td>2.8"</td></tr> <tr><td>210.5"</td></tr> <tr><td>Atterberg Limits</td></tr> <tr><td>Unconfined Compr.</td></tr> <tr><td>Hydrometer/Sieve</td></tr> <tr><td>Moisture: 27.4%</td></tr> <tr><td>186"-191"</td></tr> <tr><td>153"</td></tr> <tr><td>Atterberg Limits</td></tr> <tr><td>Unconfined Compr.</td></tr> <tr><td>Hydrometer/Sieve</td></tr> <tr><td>138"-144"</td></tr> <tr><td>127"</td></tr> <tr><td>118"</td></tr> <tr><td>Moisture: 26.1%</td></tr> <tr><td>100"</td></tr> <tr><td>Atterberg Limits</td></tr> <tr><td>Unconfined Compr.</td></tr> <tr><td>Hydrometer/Sieve</td></tr> <tr><td>51"-57"</td></tr> <tr><td>47"</td></tr> <tr><td>Moisture: 38.0%</td></tr> <tr><td>41"</td></tr> <tr><td>33.5"</td></tr> <tr><td>33"</td></tr> <tr><td>Atterberg Limits</td></tr> <tr><td>Unconfined Compr.</td></tr> <tr><td>Hydrometer/Sieve</td></tr> <tr><td>21.5"</td></tr> <tr><td>12"-18"</td></tr> </table> </div> <div style="margin-left: 10px;"> <p>Atterberg Limits: Non-Plastic Cohesion: 295 psf % Passing No. 200 Sieve: 8.6</p> <p>Gray fine sand w/slight inorganic clay and shell content.</p> <p>Atterberg Limits: Liquid Limit 66; Plastic Limit 22; Plasticity Index 44 Cohesion: 330 psf % Passing No. 200 Sieve: 79.6</p> <p>Gray inorganic clay w/slight to medium sand.</p> <p>Gray fine sand w/slight inorganic clay and shell.</p> <p>Gray fine sand w/slight shell.</p> <p>Gray fine sand with slight clay and shell content.</p> <p>Atterberg Limits: Non-Plastic *Unconfined Compression was not attainable-sand sample broke apart % Passing No. 200 Sieve: 6.7</p> <p>Gray inorganic clay with high shell lens.</p> <p>Gray inorganic clay with high sand and shell.</p> <p>Dark brown organic clay w/sand & shell.</p> <p>Gray inorganic clay w/slight sand and shell.</p> <p>Atterberg Limits: Non-Plastic Cohesion: 365 psf % Passing No. 200 Sieve: 13.3</p> <p>Gray fine sand with high shell fragments and slight clay lenses.</p> </div> </div> | | 2.8" | 210.5" | Atterberg Limits | Unconfined Compr. | Hydrometer/Sieve | Moisture: 27.4% | 186"-191" | 153" | Atterberg Limits | Unconfined Compr. | Hydrometer/Sieve | 138"-144" | 127" | 118" | Moisture: 26.1% | 100" | Atterberg Limits | Unconfined Compr. | Hydrometer/Sieve | 51"-57" | 47" | Moisture: 38.0% | 41" | 33.5" | 33" | Atterberg Limits | Unconfined Compr. | Hydrometer/Sieve | 21.5" | 12"-18" | | | <table border="1"> <tr><td>Texture</td><td>Clay, Sand & Shell</td></tr> <tr><td>Visual Classification (USCS)</td><td>CH, SM, & SC</td></tr> <tr><td>Color</td><td>Gray</td></tr> <tr><td>Relative Moisture</td><td>Moist</td></tr> <tr><td>Consistency</td><td>Semi-solid</td></tr> <tr><td>Porosity or Structure</td><td>Banded</td></tr> </table> | | Texture | Clay, Sand & Shell | Visual Classification (USCS) | CH, SM, & SC | Color | Gray | Relative Moisture | Moist | Consistency | Semi-solid | Porosity or Structure | Banded |
| | | 2.8" | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 210.5" | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Atterberg Limits | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Unconfined Compr. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Hydrometer/Sieve | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Moisture: 27.4% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 186"-191" | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 153" | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Atterberg Limits | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Unconfined Compr. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hydrometer/Sieve | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 138"-144" | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 127" | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 118" | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Moisture: 26.1% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 100" | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Atterberg Limits | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Unconfined Compr. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hydrometer/Sieve | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 51"-57" | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 47" | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Moisture: 38.0% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 41" | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 33.5" | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 33" | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Atterberg Limits | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Unconfined Compr. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hydrometer/Sieve | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21.5" | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12"-18" | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Texture | Clay, Sand & Shell | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Visual Classification (USCS) | CH, SM, & SC | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Color | Gray | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Relative Moisture | Moist | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Consistency | Semi-solid | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Porosity or Structure | Banded | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

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|---|--|--|--|---|--|
| Materials Testing Report | | SOIL CONSULTANTS, INC. P.O. Drawer 698, Charleston, S.C. 29402 | | Unconfined Compression Test ASTM D 2166 | |
| Project And State: Hunley Project Charleston, S.C. | | | | Sample Location: HUPB | |
| Field Sample No. 3A | | Depth from tube bottom: 12"-18" | | Sample Description: Gray fine sand w/ high shell, slight clay and slight clay lenses. | |
| Type of Sample: Pushed | | SCI Project: 99-879 | | Cohesion: 365 psf | |
| | | Calculations by: Approved By: | | SMS AJM | |
| | | Date: | | July 19, 1999 | |



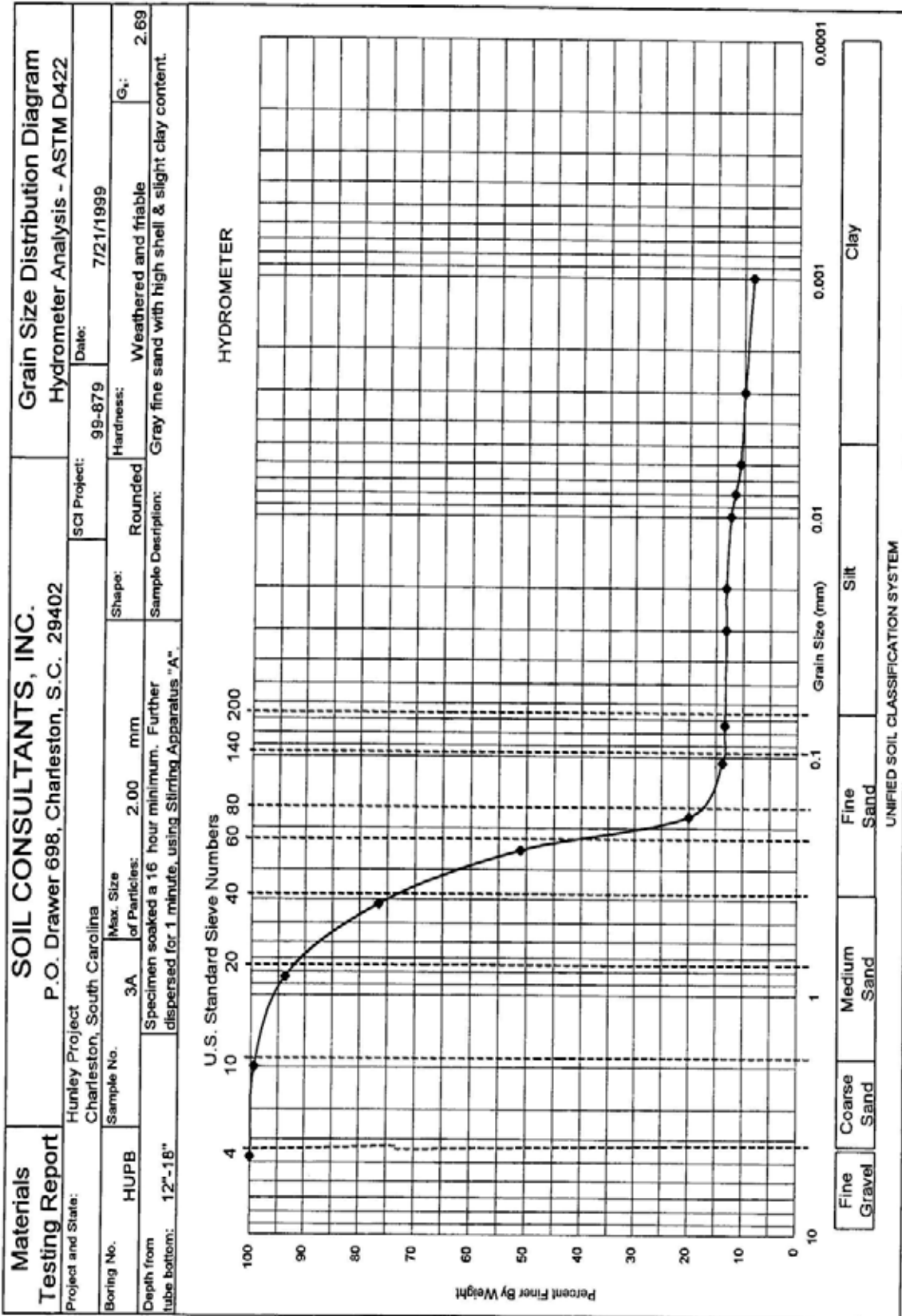
| Index Test Data | | | |
|-----------------|------|-------------------|-------------|
| VUSCS: | SM | Liquid Limit | Non-Plastic |
| % Finer #200 | 13.3 | Plastic Limit | Non-Plastic |
| G(s) | 2.69 | Plasticity Index: | Non-Plastic |



| Undisturbed Specimen Data | | | |
|------------------------------------|---------------------|-------------------|-----|
| Height (inches): | 5.6 | Diameter (inches) | 2.8 |
| Method of Preparation: | Trimmed | L/D: | 2 |
| Average Rate of Strain to Failure: | 0.056 inches/minute | | |

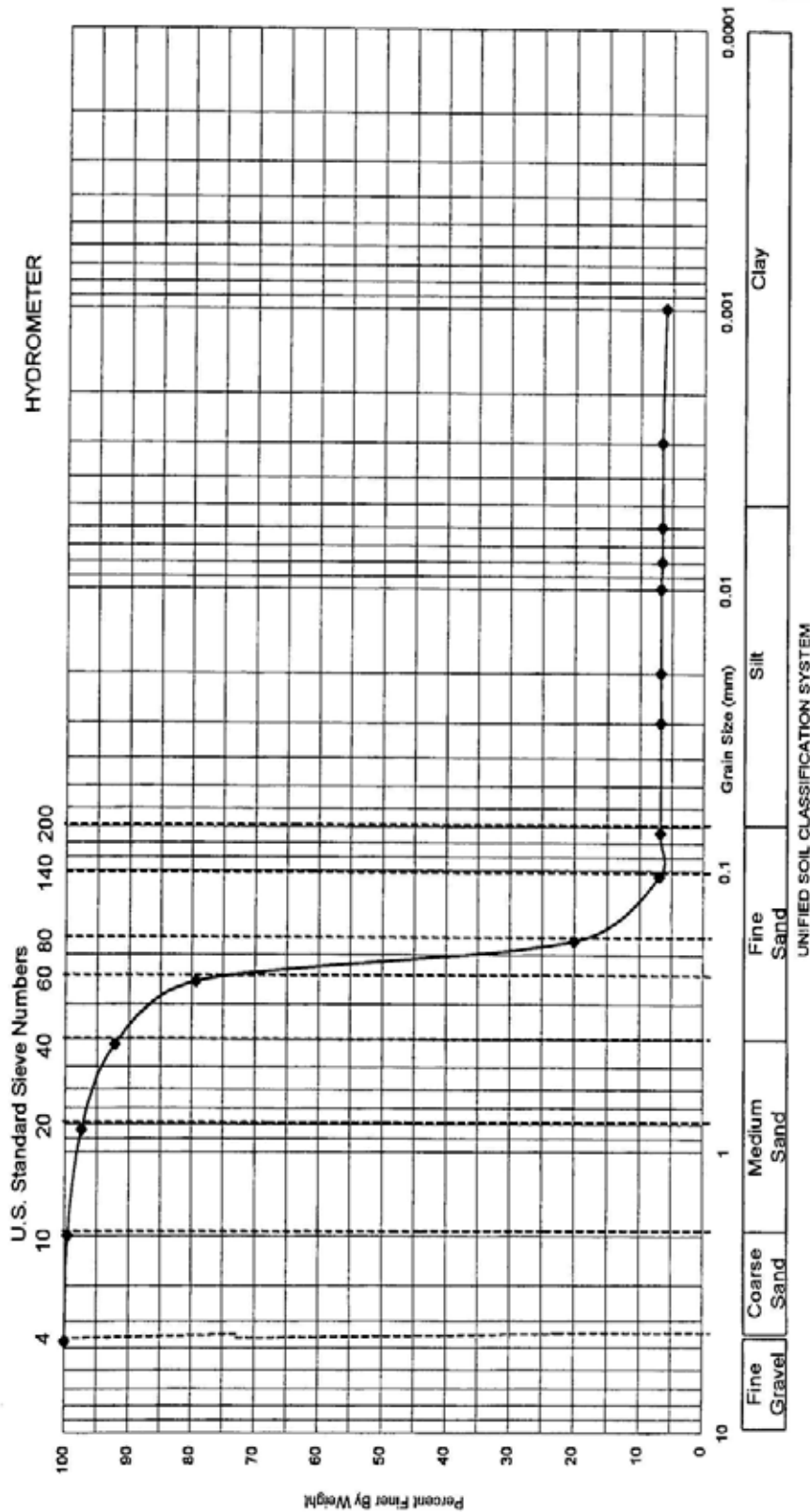
| Density | | Moisture Content | | | Time of Consolidation (hrs.) | Minor Principal Stress (psi) | Maximum Deviator Stress (psi) | Axial Strain at Failure (%) |
|-------------------|-------------------|------------------|-------------------------------------|---------------------------|------------------------------|------------------------------|-------------------------------|-----------------------------|
| Initial Wet (pcf) | Initial Dry (pcf) | Start of Test | Deg. of Saturation At Start of Test | End of Test Entire Sample | | | | |
| 127.5 | 99.8 | 27.8 | | 21.7 | | 5.1 | 2.5 | |
| | | | | | | | | |

Remarks:



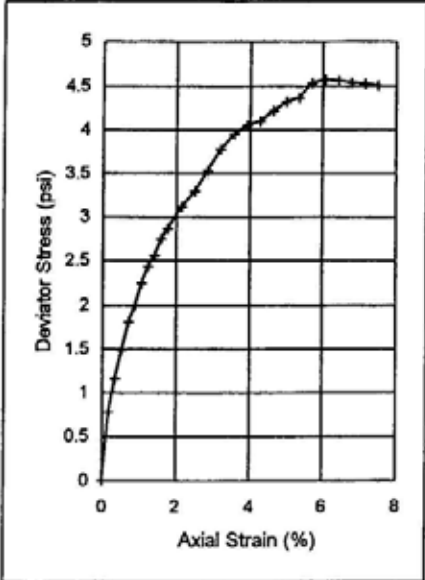
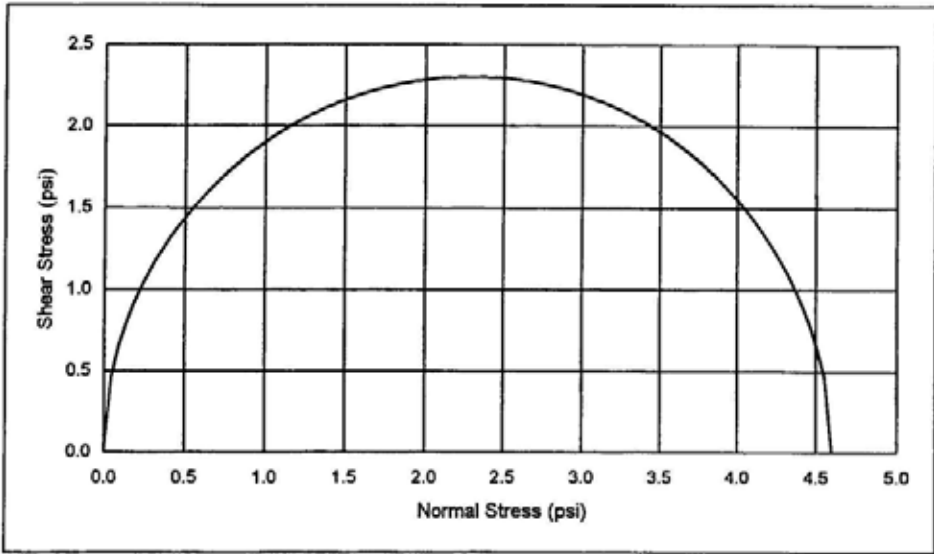
Respectfully Submitted: *Suzanne M. Stroh*

| | | | | | |
|---------------------------------|--|--|--|--|--|
| Materials Testing Report | | SOIL CONSULTANTS, INC. | | Grain Size Distribution Diagram | |
| Project and State: | | P.O. Drawer 698, Charleston, S.C. 29402 | | Hydrometer Analysis - ASTM D422 | |
| Boring No. HUPB | | Hunley Project Charleston, South Carolina | | Date: 7/20/1999 | |
| Depth from tube bottom: 51"-57" | | Sample No. 3A | | SCI Project: 99-879 | |
| | | Max. Size of Particles: 2.00 mm | | Hardness: Weathered and friable | |
| | | Specimen soaked a 16 hour minimum. Further dispersed for 1 minute, using Stirring Apparatus "A". | | Shape: Rounded | |
| | | | | Sample Description: Gray fine sand with slight clay and shell content. | |
| | | | | G _s : 2.65 | |

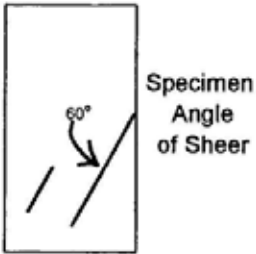


Respectfully Submitted: *Eugene M. Stroh*

| | | | | | |
|--|------------------------|--|-------------------------|---|--|
| Materials Testing Report | | SOIL CONSULTANTS, INC. P.O. Drawer 698, Charleston, S.C. 29402 | | Unconfined Compression Test ASTM D 2166 | |
| Project and Site: Hunley Project Charleston, S.C. | | | | Sample Location: HUPB | |
| Field Sample No. 3A | | Depth from tube bottom: 138"-144" | | Sample Description: Gray inorganic clay with slight to medium sand content. | |
| Type of Sample: Pushed | SCI Project: 99-879 | Cohesion: 330 psf | Calculations by: SMS | Date: July 16, 1999 | |
| | | | Approved by: AJM | | |



| Index Test Data | | | |
|-----------------|------|------------------|----|
| VUSCS: | CH | Liquid Limit | 66 |
| % Finer #200 | 79.6 | Plastic Limit | 22 |
| G(s) | 2.69 | Plasticity Index | 44 |

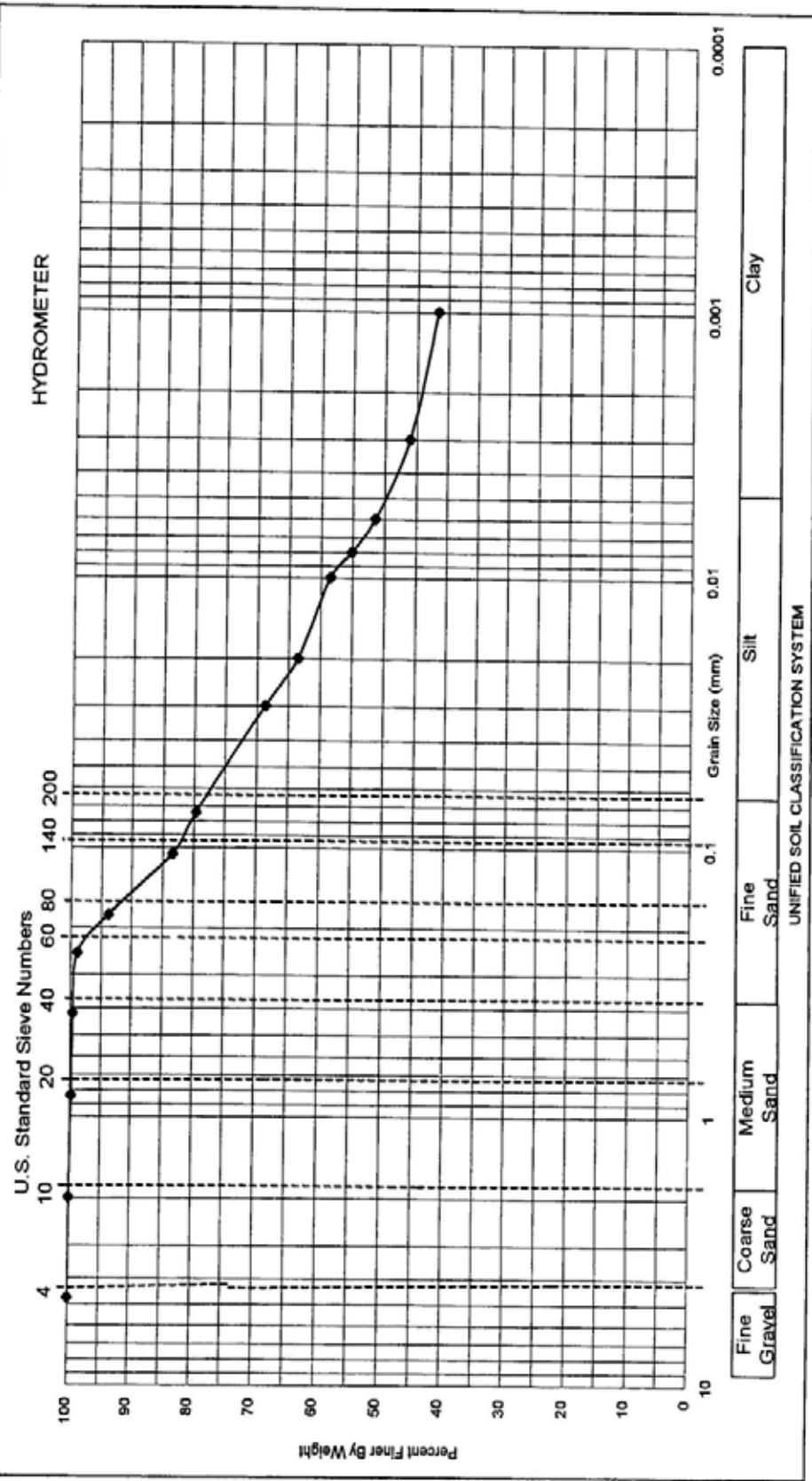


| Undisturbed Specimen Data | | | |
|------------------------------------|---------------------|-------------------|-----|
| Height (inches): | 5.6 | Diameter (inches) | 2.8 |
| Method of Preparation: | Trimmed | L/D: | 2 |
| Average Rate of Strain to Failure: | 0.056 inches/minute | | |

| Density | | Moisture Content | | | Time of Consolidation (hrs.) | Minor Principal Stress (psi) | Maximum Deviator Stress (psi) | Axial Strain at Failure (%) |
|-----------|-----------|------------------|-------------------------------------|---------------------------|------------------------------|------------------------------|-------------------------------|-----------------------------|
| Wet (pcf) | Dry (pcf) | Start of Test | Deg. of Saturation At Start of Test | End of Test Entire Sample | | | | |
| 103.3 | 67.3 | 53 | | 53.4 | | 4.6 | 6.1 | |
| | | | | | | | | |

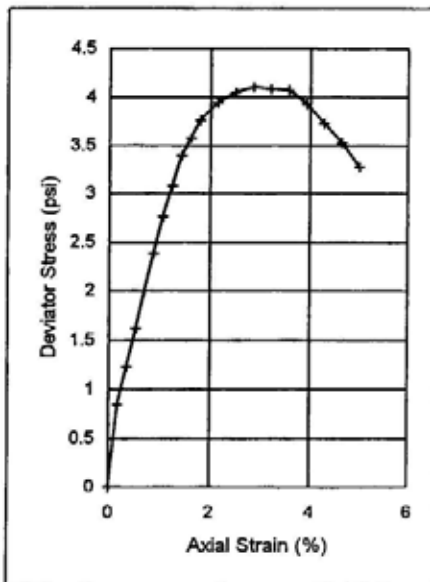
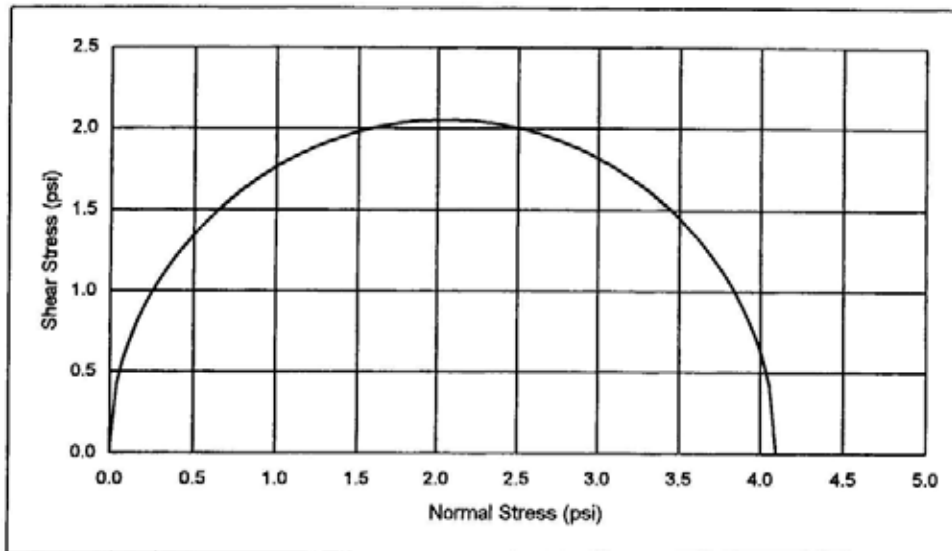
Remarks:

| | | | | | |
|-----------------------------------|--|--|--|--|--|
| Materials Testing Report | | SOIL CONSULTANTS, INC. | | Grain Size Distribution Diagram | |
| Project and State: | | P.O. Drawer 698, Charleston, S.C. 29402 | | Hydrometer Analysis - ASTM D422 | |
| Boring No. HUPB | | Hunley Project Charleston, South Carolina | | Date: 7/21/1999 | |
| Depth from tube bottom: 138"-144" | | Sample No. 3A | | SCI Project: 99-879 | |
| | | Max. Size of Particles: 0.84 mm | | Hardness: Soft | |
| | | Specimen soaked a 16 hour minimum. Further dispersed for 1 minute, using Stirring Apparatus "A". | | Shape: Rounded | |
| | | | | Sample Description: Gray inorganic clay with slight to medium sand content | |
| | | | | G _s : 2.69 | |

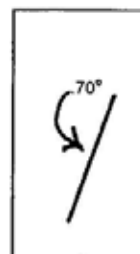


Respectfully Submitted: *Suzanne M. Stroh*

| | | | | | |
|---|------------------------|--|---|--|--|
| Materials Testing Report | | SOIL CONSULTANTS, INC. P.O. Drawer 698, Charleston, S.C. 29402 | | Unconfined Compression Test ASTM D 2166 | |
| Project And State: Hunley Project Charleston, S.C. | | | | Sample Location: HUPB | |
| Field Sample No. 3A | | Depth from tube bottom: 186"-191" | Sample Description: Gray fine sand with slight clay & shell content. | | |
| Type of Sample: Pushed | SCI Project: 99-879 | Cohesion: 295 psf | Calculations By: Approved By: SMS AJM | Date: July 19, 1999 | |



| Index Test Data | | | |
|-----------------|-------|-------------------|-------------|
| VUSCS: | SM-SP | Liquid Limit | Non-Plastic |
| % Finer #200 | 8.6 | Plastic Limit | Non-Plastic |
| G(s) | 2.68 | Plasticity Index: | Non-Plastic |

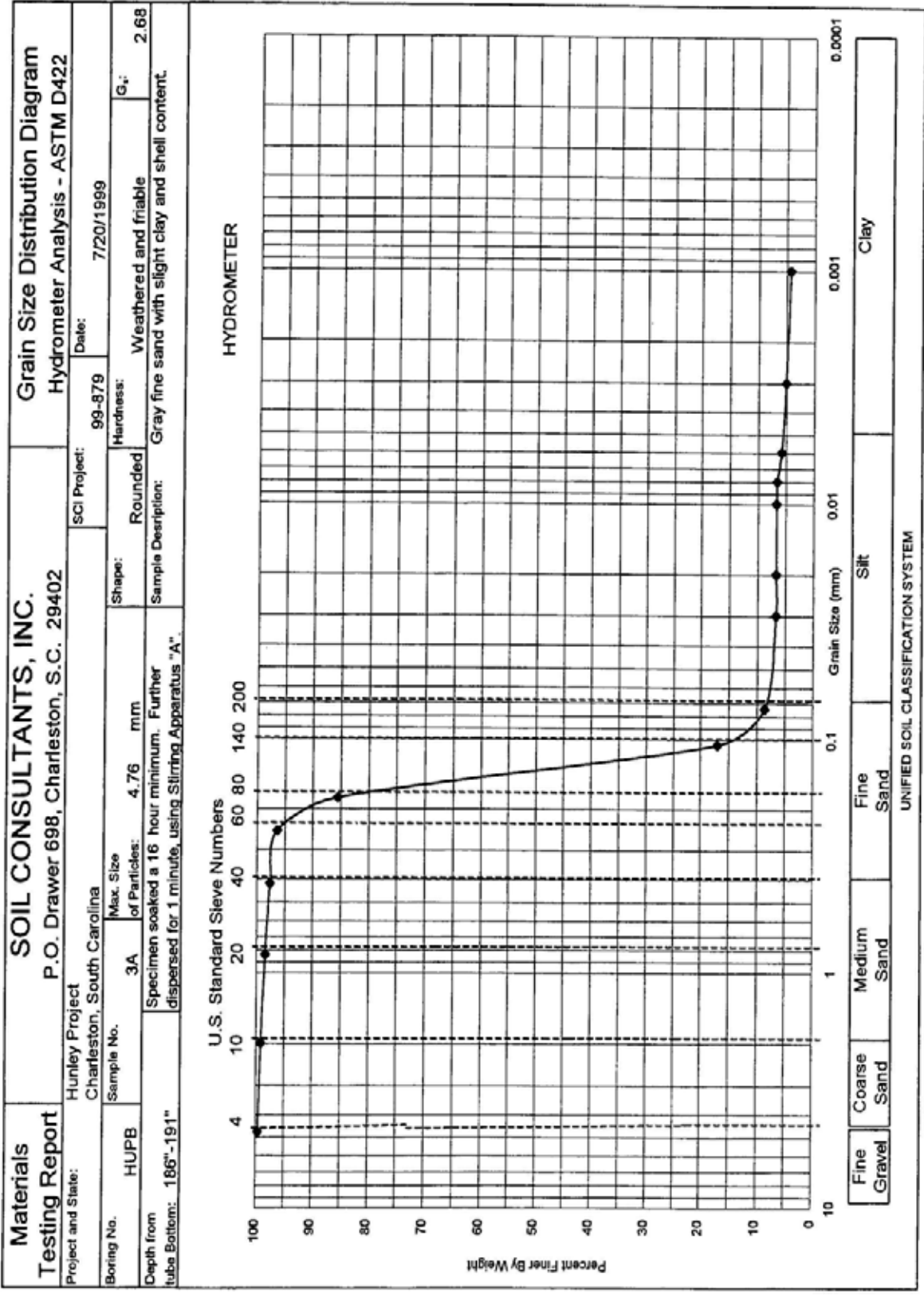


Specimen
Angle
of Shear

| Undisturbed Specimen Data | |
|------------------------------------|---------------------|
| Height (inches): | 5.6 |
| Diameter (inches): | 2.8 |
| Method of Preparation: | Trimmed |
| L/D: | 2 |
| Average Rate of Strain to Failure: | 0.056 inches/minute |

| Density | | Moisture Content | | | Time of Consolidation (hrs.) | Minor Principal Stress (psi) | Maximum Deviator Stress (psi) | Axial Strain at Failure (%) |
|-------------------|-------------------|------------------|-------------------------------------|---------------------------|------------------------------|------------------------------|-------------------------------|-----------------------------|
| Initial Wet (pcf) | Initial Dry (pcf) | Start of Test | Deg. of Saturation At Start of Test | End of Test Entire Sample | | | | |
| 121.3 | 95.5 | 27 | | 26.2 | | 4.1 | 2.86 | |
| | | | | | | | | |

Remarks:



Respectfully Submitted: *Suzanne M. Stud*



APPENDIX E

Helping the *H.L. Hunley* “Complete the Journey”

Helping the *H.L. Hunley* "Complete the Journey"

Mark Hansen, Nancy T. DeWitt and Dana Wiese



Figure 1. Conrad Wise Chapman's contemporary painting of the *H.L. Hunley*.

In 1864, the Confederate submarine *H.L. Hunley* was the first submersible boat to successfully attack and sink an enemy ship under water with the use of a torpedo. For reasons still unknown, the *Hunley* disappeared after the attack until it was found in 1995. USGS scientists were asked to provide *H.L. Hunley* archeologists with geological information which was needed to reveal the stratigraphic structure around the wreck site and to better understand the submarine's burial sequence. Side-scan sonar, chirp and 3.5 kHz seismic data, and 20' sediment cores were collected to map the stratigraphic structure. This information was necessary for planning and engineering purposes which ultimately lead to a successful raising of the *H.L. Hunley* on August 8, 2000.

Introduction

In May, 1999 the United States Geological Survey Center for Coastal Geology and Regional Marine Studies assisted the National Park Service (NPS), South Carolina Institute of Archeology and Anthropology (SCIAA) and the US Naval Historical Center (NHC) in their quest to raise for conservation the Civil War submarine, *H.L. Hunley* (Figure 1). Additionally, there was an archeological interest in *Hunley's* fateful victim, the Federal blockade ship, *USS Housatonic*.

USGS scientists have been involved in coastal studies for several years in South Carolina as part of the Coastal and Marine Geology Program's South Carolina Coastal Ero-

sion Study. This study focused primarily on mapping the shallow coastal geology framework and developing a sediment inventory in the Charleston area. Unknowingly, this study acquired seismic, side-scan sonar, and sediment cores within a one-half mile of the *H.L. Hunley* wreck site. It was through this study that archeologists at the NHC contacted the USGS for existing geological information in the vicinity of the *H.L. Hunley* and later for additional scientific assistance.

Historical Background

During the Civil War, Confederate inventors James McClintock and Baxter Watson, constructed several prototype and operational submersible

boats for the purpose of delivering an offensive torpedo. In 1863, an operational submersible was shipped via flat car from Mobile, AL to Charleston, SC to take up action against Federal warships blockading Charleston Harbor. The model sent to Charleston had a length of 40 ft., depth of 5 ft., and was powered by a crew of 9 who turned a hand crank attached to a 3.5 ft. propeller (Figure 2). Attached to the bow of the submarine was a 22 ft. pine spar which held a dagger tipped, 90 pound blackpower charge torpedo, triggered by a crew member via a trip line. After the first crew of the submersible was lost during a sea-trial, Horance L. Hunley, a shareholder and engineer in the Mobile group building submarines, was sent to take command upon its recovery. During another sea-trial in Charleston Harbor, *Hunley* apparently made a fatal ballast mistake which killed him and his

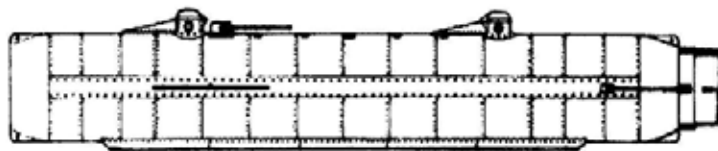


Figure 2. Artist rendering of *H.L. Hunley* (longitudinal view).

crew. Lt. George Dixon, also from the Mobile group, was then sent to Charleston to take command upon its second recovery. On February 17, 1864, Dixon and his crew fatefully launched the *H.L. Hunley* from Sullivan's Island to attack the Federal blockade ship *USS Housatonic* which laid at anchor 4 miles offshore. Observers aboard the *USS Housatonic* reported the *H.L. Hunley* rammed the stern quarter amidst small arms fire, planted its torpedo and remotely activated it with such a large explosion that it sank the *USS Housatonic* in minutes. The *H.L. Hunley* never returned to Sullivan's Island for causes which are still unknown. Upon its discovery by the novelist Clive Custer in 1995, it was determined that the *H.L. Hunley* sank one-thousand ft. from the final resting place of the *USS Housatonic*.

Geological Investigations

The USGS provided geological expertise to Hunley archeologists to help reveal the geologic structure of



Figure 3. *R/V Gilbert* retrieving a sediment core near the *H.L. Hunley*, and close-up of coring rig.

the sediment layers around the Hunley and the *Housatonic*, and to understand the submarine burial sequence. This information was crucial for planning purposes which would ultimately lead to a successful resurrection and preservation of these historical entities.

In May 1999, USGS scientist collected chirp (high resolution) and 3.5 kHz seismic sub-bottom profile data, and 500 kHz sidescan near and over the Hunley and *Housatonic* wreck sites aboard the *R/V Gilbert* (Figure 3). The chirp sub-bottom profile sonar sensor is a high-resolution system, which can resolve micro-bedding (sedimentary

layers down to 25 cm thick. Five 20-ft long sediment cores were collected 25 ft. from the Hunley, and three cores were taken near the *Housatonic* site. The cores were used for ground truthing seismic data, additionally, they were analyzed by a local engineering firm for their geotechnical properties. Geotechnical properties of the surrounding sediments were needed to assess the bearing capacity of the underlying sediments during the excavation and raising process.

Sidescan sonar images revealed surficial expressions of the submarines two hatches (Figure 4). It is assumed

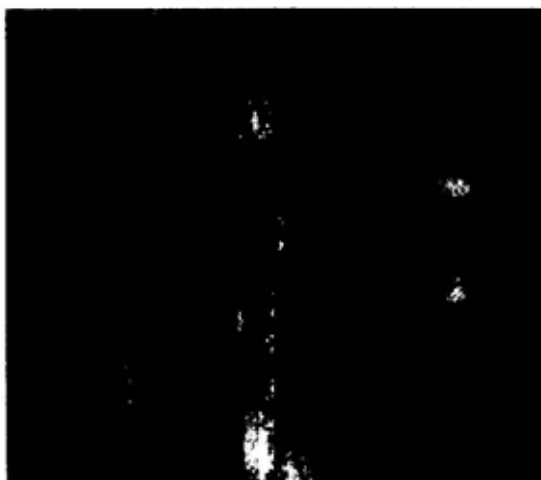


Figure 4. Side scan sonar image revealing Hunley's hatch covers below the sea floor.

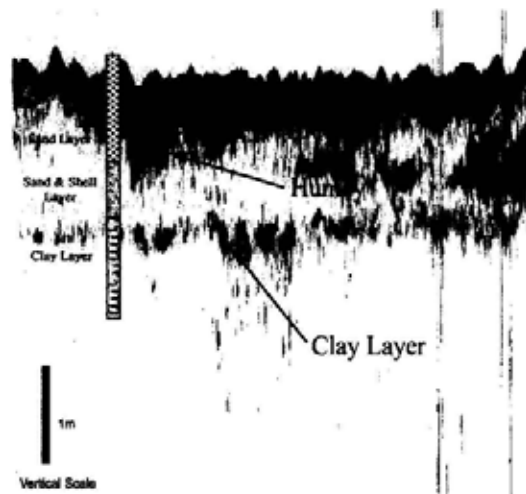


Figure 5. Example of one chirp seismic image and corresponding core log over center section of submarine.

that slight topographic depressions over the hatch covers were detected by the sonar. Diver observations by Hunley's archeologist during partial excavations in 1998 revealed the submarine was resting horizontally on a firm sedimentary layer buried in fine to medium size sand approximately two feet below the sea floor. Interpretations of the seismic and core data confirmed diver observations. The general outline of the Hunley is evident in several of the chirp profile lines that run perpendicular over the center section of the submarine (Figure 5). Interpretations of the chirp data suggest the sediments above the keel of the Hunley appear to be rather homogeneous. Core logs confirmed the chirp data interpretations in that sediments above the keel were depositional/erosional sequences of ebb-tidal delta sands. Thin layers of mud and shelly sand were interspersed in this top layer. At 9 ft. below the sea floor, the Hunley was resting on a Holocene (<10,000 ybp) dense clay layer, which has a consistency of modeling clay. It is this layer that probably kept the submarine from sinking deeper into tidal sediments over the past 130 years.

The wreck of *USS Housatonic* became a navigational hazard and in the early 1900's it was reportedly dynamited several times to eliminate the hazard. The archeological interest in the *USS Housatonic* was primarily to assess the amount of damage inflicted by the *H.L. Hunley*. Seismic data over the *USS Housatonic* site did not reveal any anomalies. Side-scan images detected several large objects near the wreck site which may have been part of the *Housatonic's* coal fired boilers. Gravel size coal pieces were found in the upper 6 ft. of two of

the sediment cores take near the wreck site. It is speculated the coal came from the *Housatonic's* coal-bunkers.

HUNLEY'S BURIAL SEQUENCE

The historical morphological changes of the Charleston Harbor ebb-tidal delta is important for explanation of the Hunley's burial sequence. Tidal flow patterns and shape of the ebb-tidal delta was radically altered when

19,000 ft. jetties were constructed at the mouth of Charleston Harbor in 1890. Prior to jetty construction, the majority of Charleston Harbor's 2.2 billion ft³ tidal prism flowed through an S-shaped main ebb-channel starting from Fort Sumter, south along Morris Island, then directly eastward at Lighthouse Inlet (Figure 6). During this time, tidal currents near the Hunley wreck are estimated to be low, ~ 1 - 2 knots. Jetty con-

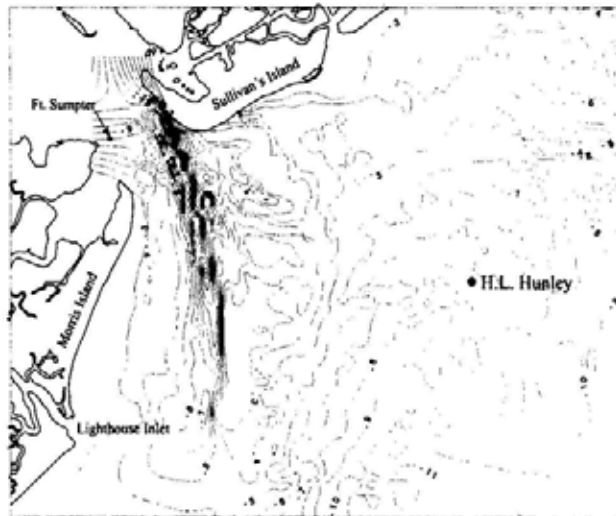


Figure 6. Bathymetric contour map of the 1880's showing location of the main ebb-channel along Morris Island and the location of the Hunley wreck site.

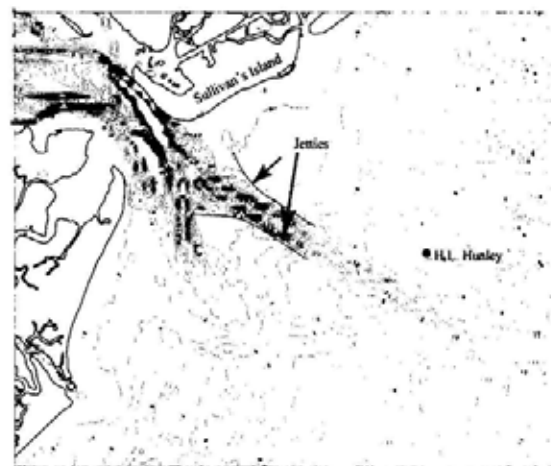


Figure 7. Location of the main ebb-channel since jetty construction and proximity to the Hunley wreck site.

struction dramatically changed tidal flow patterns by diverting the main ebb-channel and tidal flow directly east, to a location 300 ft. from the Hunley wreck site. Measured current flows on the Hunley site are 4-5 knots (Figure 7).

The Hunley sank on the eastern flank of the then existing ebb-tidal delta, which consisted of fine to medium sands. Tidal currents were relatively low, consequently minimal scouring and subsequent settling occurred, resulting in the submarine being fully exposed on the sea-floor. Twenty-five years after the incident, the jetties induced strong tidal current over the Hunley resulting in rapid scouring and settling. The scouring/settling process continued until contact was made with the firm Holocene clay layer, at which point settling ceased. This sequence and time-frame is confirmed by biofouling studies which indicate that the submarine was only exposed on the sea-surface for 15-20 years. We suggest that the Hunley's rather rapid burial into anoxic (reduced oxygen) deltaic sediments helped preserve it by slowing the oxidation (rusting) rate.

Scientific information provided by the USGS to Hunley archeologists ultimately lead - helping the *H.L. Hunley* "complete the journey"



Courtesy of the Friends of the Hunley and the National Geographic Society

Figure 8. Chief archeologist Dr. Dave Conlin (NPS) describes recover efforts using miniature models.

This report is preliminary and has not been reviewed for conformity with U. S. Geological editorial standards or with the North American Stratigraphic Code. Reference therein to any specific commercial product, process, or service by trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof.



Figure 9. Hunley just lifted out of water and about to be set on barge.



Figure 10. Hunley in lifting sling entering restoration laboratory at the US Naval Base in Charleston, SC

REFERENCE

Murphy, Larry
Editor, 1998, *H.L. Site Assessment*, National Park Service, Naval Historical Center, and South Carolina Institute of Archaeology and Anthropology, pp198.

For further information, please contact:

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APPENDIX F

Sediment Accumulation Rates Near the *H.L. Hunley* and *USS Housatonic*

Sediment Accumulation Rates Near the *H.L. Hunley* and
USS Housatonic

Marci Marot and Charles Holmes
U. S. Geological Survey
St. Petersburg, FL

Submitted to:

Dr. David Conlin
Underwater Archaeology Branch
Naval Historical Center
Washington D.C.



United States Department of the Interior

U.S. GEOLOGICAL SURVEY

Average sediment accumulation rates were determined at two sites adjacent to the Civil War submarine *H. L. Hunley* and the USS *Housatonic*. The short-lived radioisotopes lead-210 and cesium-137 each provide an independent method for calculating sediment accumulation rates. Combined, these nuclides can give a good estimate of sedimentation rates during the past 100 years.

^{210}Pb (half-life = 22.3 years) is a naturally occurring radioisotope which is produced in the atmosphere by the decay of ^{222}Rn . ^{210}Pb is rapidly removed from the atmosphere by precipitation and enters surface waters where it is quickly absorbed onto settling particles which are subsequently buried. The decay of ^{226}Ra within the sediment also produces ^{210}Pb . This background or "supported" activity is constant over time and is subtracted from the total measured ^{210}Pb activity. The atmospheric or "excess" ^{210}Pb in the sediment undergoes radioactive decay, therefore the decrease in excess ^{210}Pb activity with depth is a function of the time it has been out of contact with the surface. The age at a given depth can be calculated by the equation:

$$t_z = \ln(A_0/A_z) * 1/\lambda$$

where A_z is the excess ^{210}Pb activity at depth z , A_0 is the initial (surface) activity ^{210}Pb , and λ is the ^{210}Pb decay constant.

^{137}Cs (half-life = 30.2 years) is an anthropogenic radioisotope which was introduced into the atmosphere by nuclear weapons testing. Similar to ^{210}Pb , ^{137}Cs is removed from the atmosphere via precipitation and becomes associated with recently deposited sediment. Ideally, the vertical depth profile of ^{137}Cs activity in a sediment core should record the deposition rate from the atmosphere measured over time. The depth of highest ^{137}Cs activity should represent the 1963/64 atmospheric fallout peak. Based on this age/depth correlation, an accumulation rate can be calculated.

Several sediment cores were collected in May 1999 at the *Hunley-Housatonic* site. Two cores, one near each vessel, were selected for radiometric analysis. Core HUSB 1B was recovered near the *Hunley* and core HOUS 3 was taken close to the

Housatonic wreckage. The cores, collected in 3 inch aluminum barrels, were transported to the laboratory and split lengthwise. A 2 cm thick interval was sampled every 10 cm from the upper 2 m of each core. The samples were wet-sieved through a 63 μm (230 mesh) sieve and both fractions were dried at 60°C. The percent dry weight of both fractions is shown in Tables 1 and 2. Sand and coarser material comprise between 21.9-96.9 and 10.1-97.1 percent of the sediment in HUSB 1B and HOUS 3, respectively.

^{210}Pb is primarily associated with fine-grained or organic material, therefore only the silt/clay fraction was used for ^{210}Pb analysis in order to eliminate dilution effects caused by coarser material. ^{210}Pb activity was determined by measuring the alpha decay of its granddaughter ^{210}Po . ^{210}Pb and ^{210}Po are assumed to be in secular equilibrium, i.e. their activities are the same. The samples were heated to 450 °C to remove any organic material, dissolved in nitric acid, spiked with a known activity of ^{209}Po as a yield tracer. The Pb and Po isotopes were extracted from the sediment by further acid leaching, and autoplated onto Ag planchets. The planchets were counted for a minimum of 24 hrs on Ortec Model 576A alpha spectrometers, which output to a PCA-II multichannel analyzer. The results are given Tables 1 and 2. Excess ^{210}Pb was calculated by subtracting the supported ^{210}Pb activity from the total measured activity. Supported ^{210}Pb activities were estimated by averaging the total ^{210}Pb activities in the lower portions of the cores where the excess activity is assumed to have decayed away. Activities from 160-202cm in core HOUS3 were not included in the estimate of ^{226}Ra activity. The increased total ^{210}Pb activities at these depths is likely due to heavy mineral-enriched sands with a high uranium content, which would lead to higher supported ^{210}Pb activities. Accumulation rates were calculated by fitting an exponential curve to the excess ^{210}Pb data and applying the above equation. This method assumes that the initial ^{210}Pb activity (A_0) has remained constant with respect to time. The sediment accumulation rate for HUSB 1B is calculated at 0.74 ± 0.25 cm/yr and 0.89 ± 0.3 cm/yr in core HOUS 3. It should be noted that these are long-term average annual accumulation rates. Sediment accumulation is most likely not continuous, but episodic, in response to storm events and seasonal riverine discharge.

Based on the above accumulation rates, portions of the cores were resampled and measured for ^{137}Cs . Two centimeter intervals were sampled from HUSB 1B between 16-30 cm and HOUS 3B was sectioned from 18-36 cm. The samples were dried in an oven at 60°C and sealed in 125 milliliter counting jars. ^{137}Cs activity was measured using the 661.6 keV gamma peak on a Canberra high-purity germanium planar detector with an active area of 2000 mm^2 covered by a thin carbon composite window. The gamma

spectra were collected and analyzed with a PC-based Aptec MCArd multichannel analyzer and associated software. Instrument calibrations were performed with an 11 line NIST traceable multi-gamma standard in a soil matrix. The counting efficiency and full width-half height resolution at 661 keV were 1.5% and 1.8 eV, respectively. ^{137}Cs was not detected in any of the samples counted from either core. The absence of measurable ^{137}Cs is most likely due to the high sand content, which dilutes the ^{137}Cs activity below detection limits.

Core HUSB 1B

| Depth (cm) | Coarse (% Dry Wt.) >0.062mm | Fines (% Dry Wt.) <0.062mm | Total Pb-210 Activity (dpm/g) | Total Pb-210 Activity Error (+/-) |
|------------|-----------------------------|----------------------------|-------------------------------|-----------------------------------|
| 0-2 | 96.9 | 3.1 | 9.51 | 0.16 |
| 10-12 | 95.8 | 4.2 | 10.30 | 0.18 |
| 20-22 | 79.9 | 20.1 | 8.02 | 0.11 |
| 30-32 | 92.7 | 7.3 | 3.93 | 0.07 |
| 40-42 | 90.3 | 9.7 | 3.70 | 0.06 |
| 50-52 | 87.9 | 12.1 | 2.72 | 0.06 |
| 60-62 | 91.2 | 8.8 | 2.85 | 0.05 |
| 70-72 | 93.3 | 6.7 | 2.85 | 0.05 |
| 80-82 | 93.3 | 6.7 | 3.14 | 0.06 |
| 90-92 | 89.5 | 10.5 | 2.75 | 0.05 |
| 100-102 | 68.6 | 31.4 | 2.06 | 0.04 |
| 110-112 | 86.9 | 13.1 | 2.97 | 0.05 |
| 120-122 | 43.2 | 56.8 | 2.38 | 0.05 |
| 130-132 | 21.9 | 78.1 | 2.25 | 0.05 |
| 140-142 | 28.8 | 71.2 | 2.76 | 0.06 |
| 150-152 | 22.1 | 77.9 | 2.97 | 0.06 |
| 160-162 | 31.7 | 68.3 | 2.79 | 0.06 |
| 170-172 | 47.5 | 52.5 | 3.10 | 0.06 |
| 180-182 | 41.5 | 58.5 | 2.79 | 0.05 |
| 190-192 | 42.7 | 57.3 | 3.38 | 0.06 |
| 200-202 | 51.0 | 49.0 | 3.29 | 0.06 |

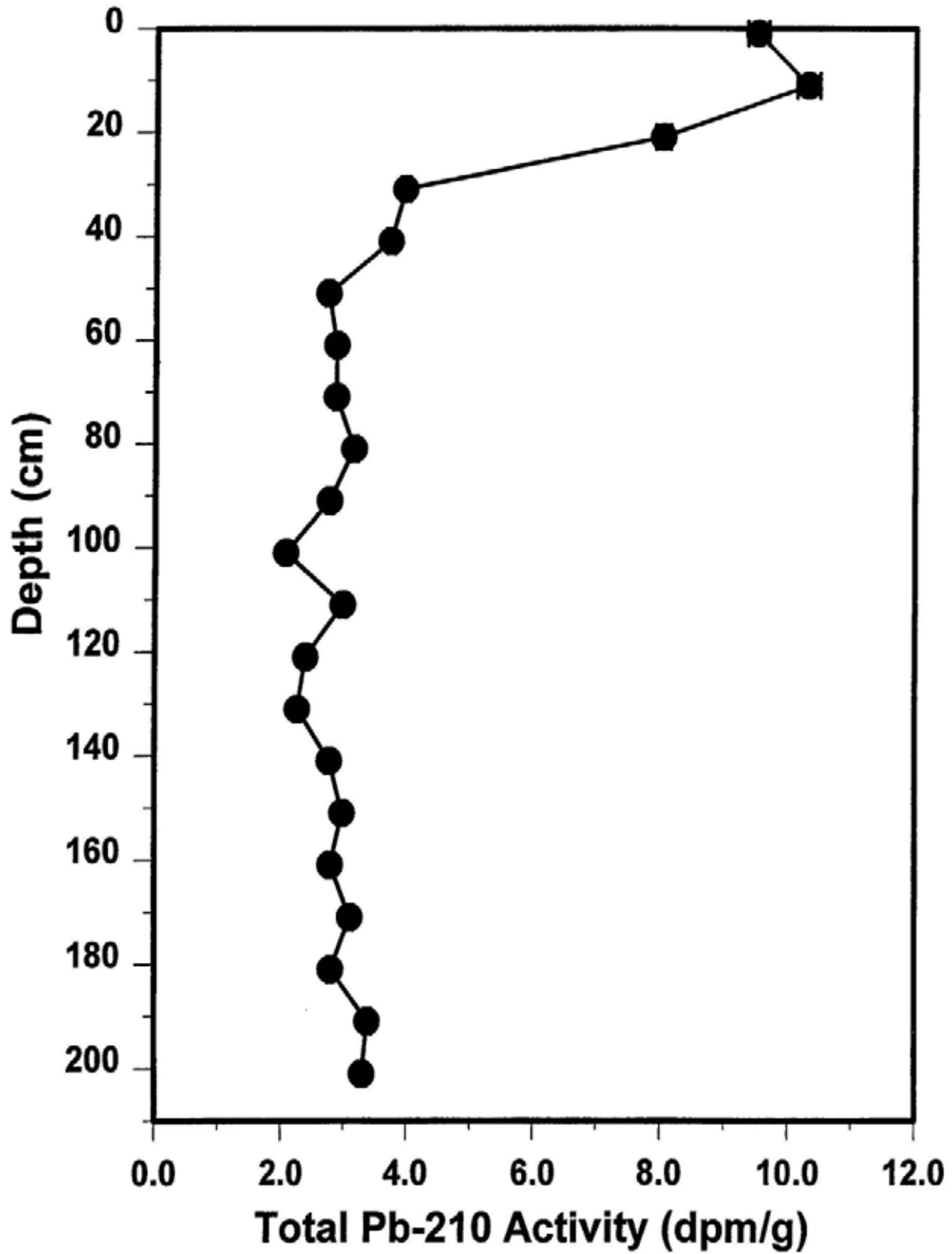
Table 1

Core HOUS 3

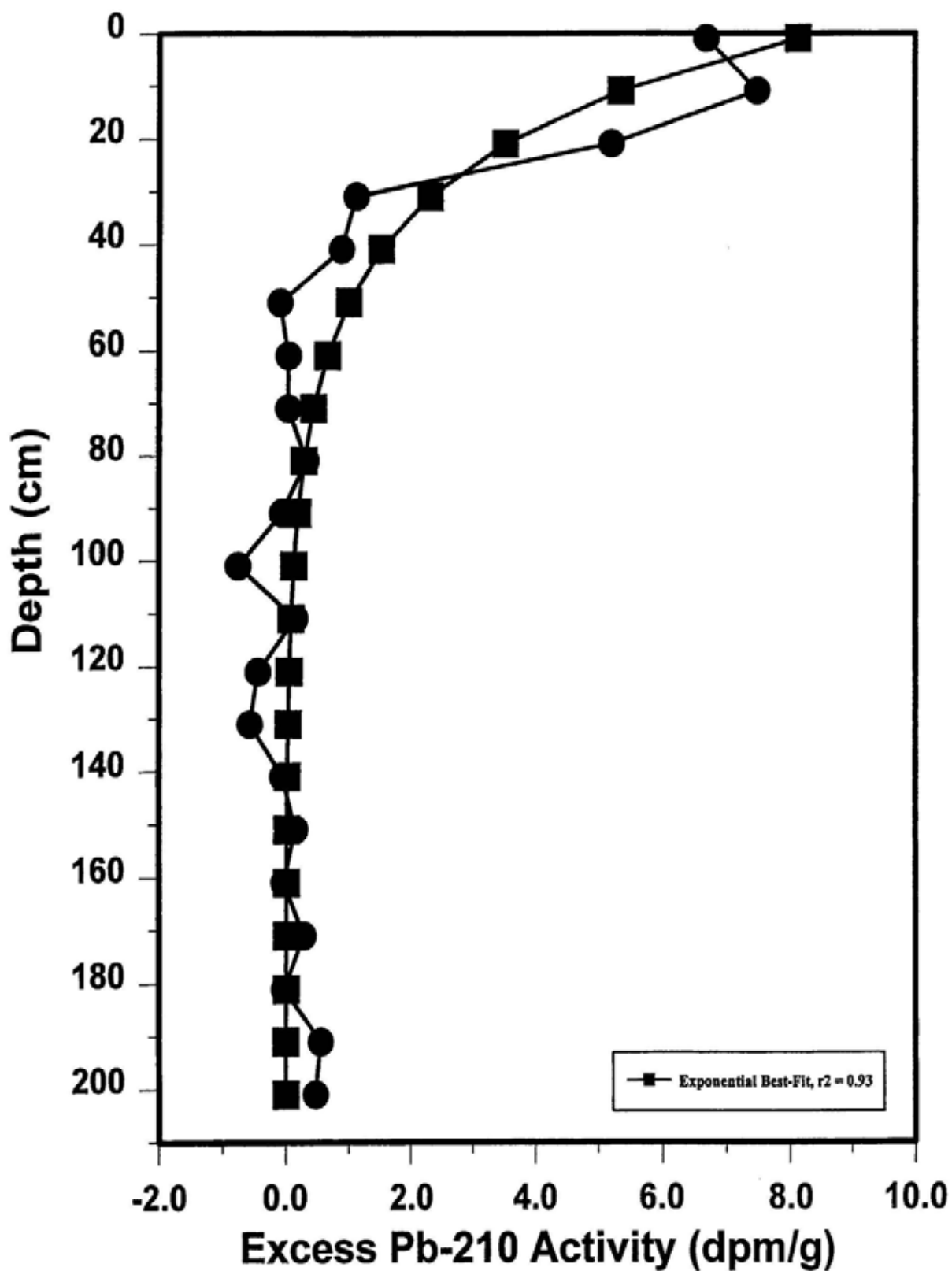
| Depth (cm) | Coarse (% Dry Wt.) >0.062mm | Fines (% Dry Wt.) <0.062mm | Total Pb-210 Activity (dpm/g) | Total Pb-210 Activity Error (+/-) |
|------------|-----------------------------|----------------------------|-------------------------------|-----------------------------------|
| 0-2 | 84.62 | 15.38 | 14.62 | 0.32 |
| 10-12 | 88.18 | 11.82 | 15.14 | 0.27 |
| 20-22 | 90.45 | 9.55 | 13.11 | 0.26 |
| 30-32 | 91.73 | 8.27 | 9.16 | 0.14 |
| 40-42 | 61.89 | 38.11 | 3.78 | 0.07 |
| 50-52 | 78.12 | 21.88 | 3.13 | 0.08 |
| 60-62 | 49.80 | 50.20 | 2.61 | 0.06 |
| 70-72 | 86.27 | 13.73 | 3.23 | 0.09 |
| 80-82 | 10.14 | 89.86 | 2.41 | 0.06 |
| 90-92 | 57.65 | 42.35 | 2.31 | 0.06 |
| 100-102 | 57.16 | 42.84 | 1.93 | 0.04 |
| 110-112 | 97.12 | 2.88 | 3.18 | 0.08 |
| 120-122 | 81.11 | 18.89 | 1.88 | 0.04 |
| 130-132 | 74.80 | 25.40 | 2.00 | 0.05 |
| 140-142 | 87.45 | 12.55 | 2.28 | 0.06 |
| 150-152 | 88.07 | 11.93 | 2.27 | 0.06 |
| 160-162 | 94.42 | 5.58 | 5.54 | 0.14 |
| 170-172 | 87.94 | 12.06 | 6.23 | 0.13 |
| 180-182 | 92.90 | 7.10 | 7.17 | 0.16 |
| 190-192 | 94.41 | 5.59 | 7.95 | 0.15 |
| 200-202 | 92.74 | 7.26 | 9.09 | 0.17 |

Table 2

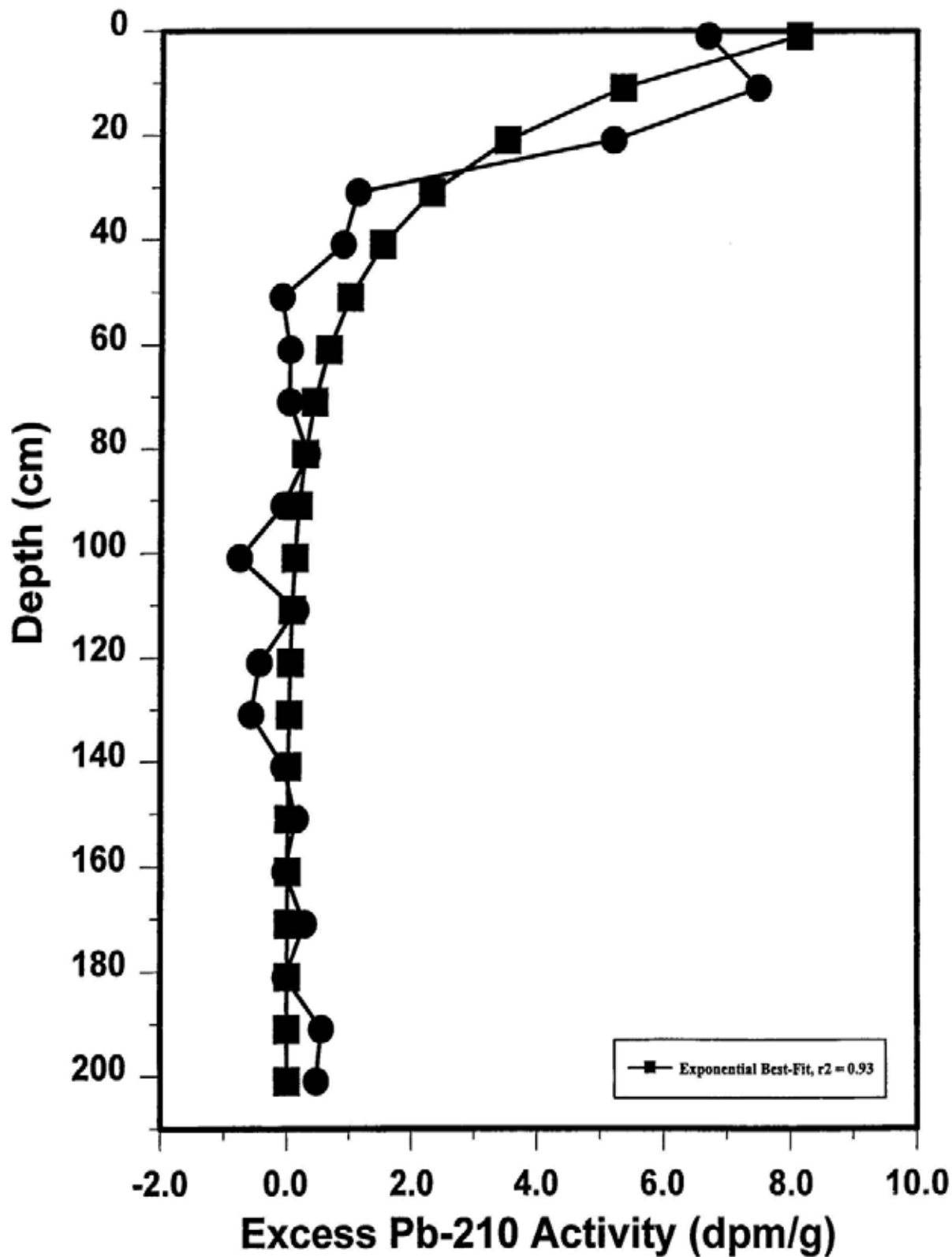
Core HUSB 1B



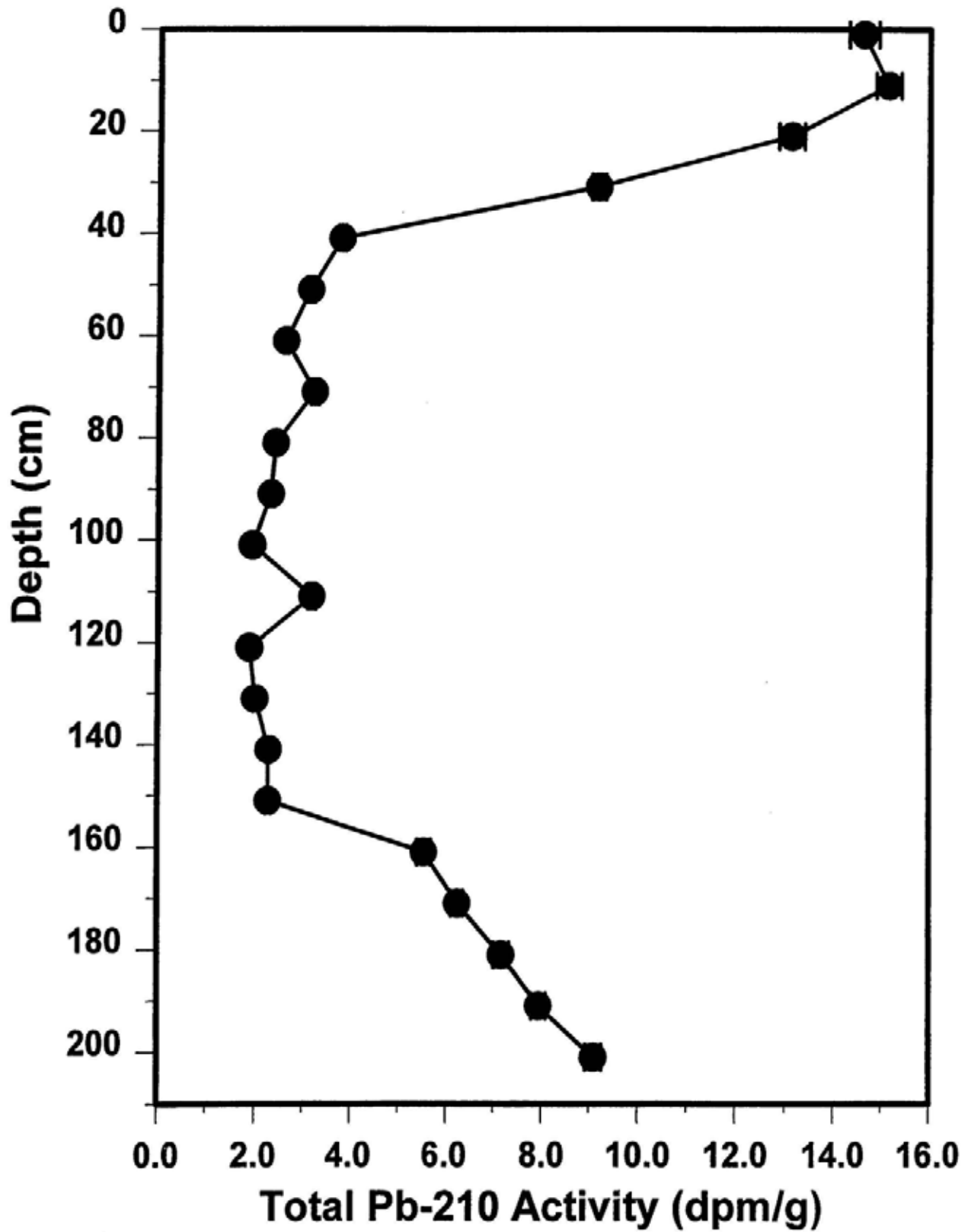
Core HUSB 1B



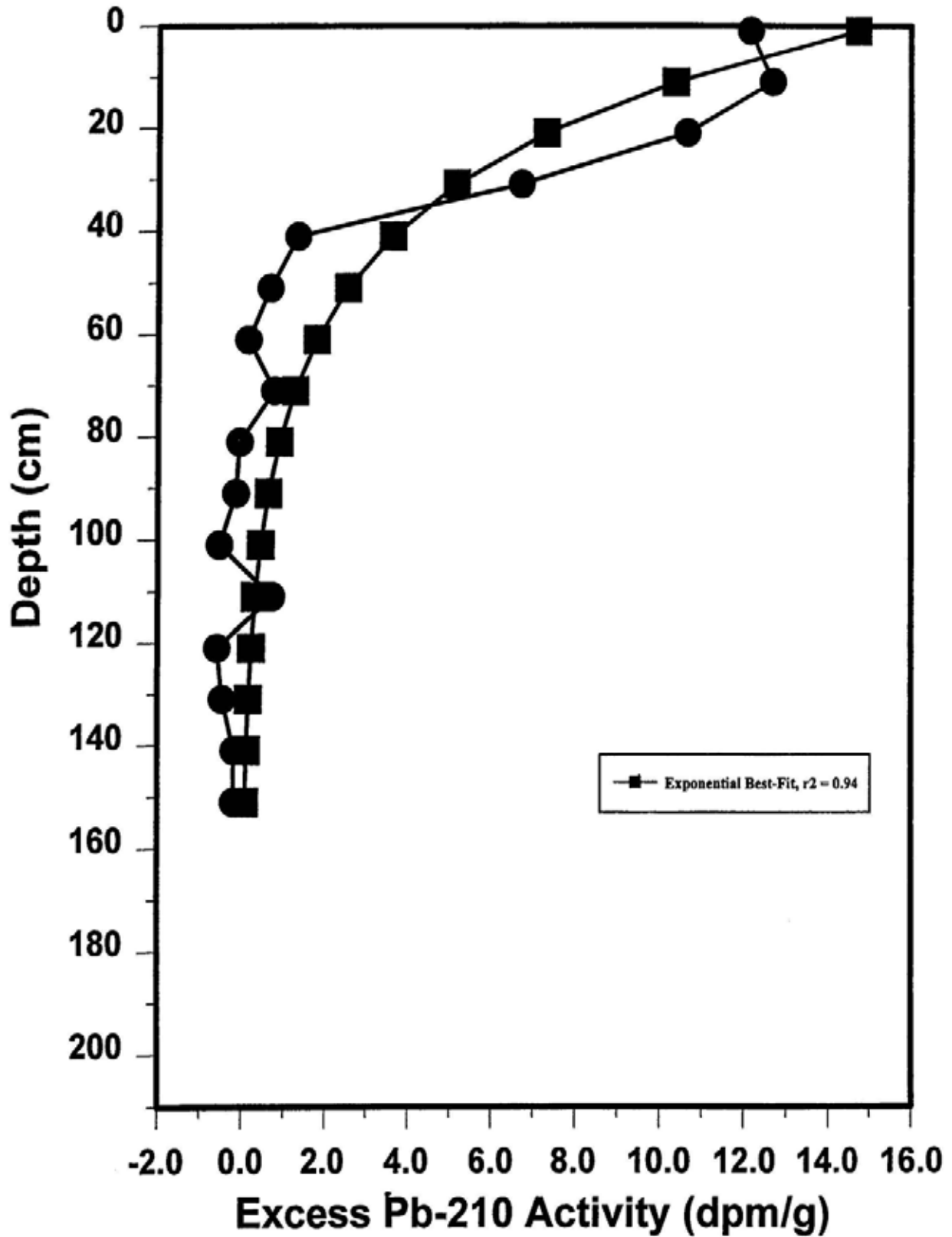
Core HUSB 1B



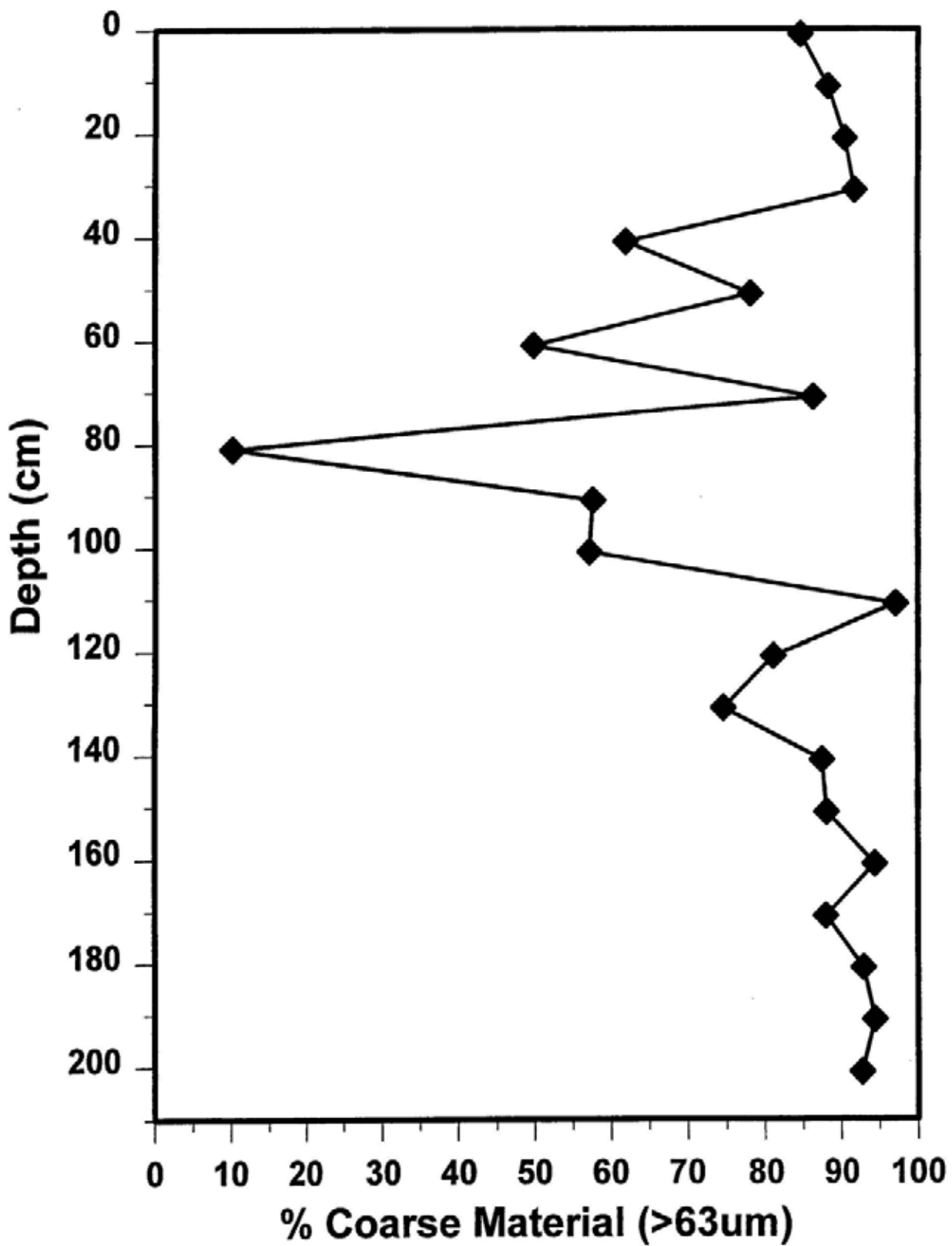
Core HOUS 3



Core HOUS 3



Core HOUS 3



SUBMERGED RESOURCES CENTER REPORTS

SUBMERGED RESOURCES CENTER PROFESSIONAL REPORTS

The Submerged Resources Center (SRC) mission is to provide direct support to park superintendents and partners responsible for stewardship of submerged resources and to enhance and facilitate public appreciation, access, understanding, and preservation of those resources. One of SRC's primary responsibilities is to disseminate research results to National Park Service managers and partners, as well as to the professional community and the public. As partial fulfillment of this responsibility, SRC established a professional report series. From 1980 to 1999, SRC was the Submerged Cultural Resource Unit (SCRU), and its publications appeared in other NPS regional series: Southwest Cultural Resources Center Professional Papers (1980-1995); Intermountain Cultural Resource Centers Professional Papers (1995-1997); and Cultural Resources Management Professional Papers (1999-2003). In 2003, the Submerged Resources Center Professional Report series began and prior reports appear sequentially in this series regardless of original designation. A discussion of the various report types in this series and a complete listing follows.

SUBMERGED CULTURAL RESOURCES ASSESSMENT

This is a first line document consisting of a brief literature search, a maritime history overview, the known or potential underwater sites in the park and preliminary recommendations for long-term management. It is designed to have immediate application to

protection and interpretation needs and to become a source document for a park's Submerged Cultural Resources Management Plan.

SUBMERGED CULTURAL RESOURCES ASSESSMENT

This reports a comprehensive examination, generally through remote sensing, of submerged lands to locate and evaluate as much of the submerged cultural resources base as possible. A comprehensive literature search would most likely be included. Occasionally, we will publish a separate Phase I (Reconnaissance) and Phase II (Evaluation) report.

SUBMERGED CULTURAL RESOURCES STUDY

A study is a document that discusses in detail all or a particular collection of underwater archeological sites in a given park. This may involve test excavations. Generally, the intended audience is managerial and professional, not the general public.

SUBMERGED CULTURAL RESOURCES REPORT OR ASSESSMENT

A site report is an exhaustive documentation of one archeological site, which may involve a partial or, if otherwise threatened, complete site excavation. An assessment is a documentation that is less exhaustive. The intended audience is primarily professional and incidentally managerial. Although the document may be useful to a park's interpretive specialists because

of its information content, it would probably not be suitable for general distribution to park visitors.

SUBMERGED CULTURAL RESOURCES SPECIAL REPORT

Special commentaries and papers on methodological or technical issues pertinent to underwater archeology are included in this title. These may or may not be about park resources or issues.

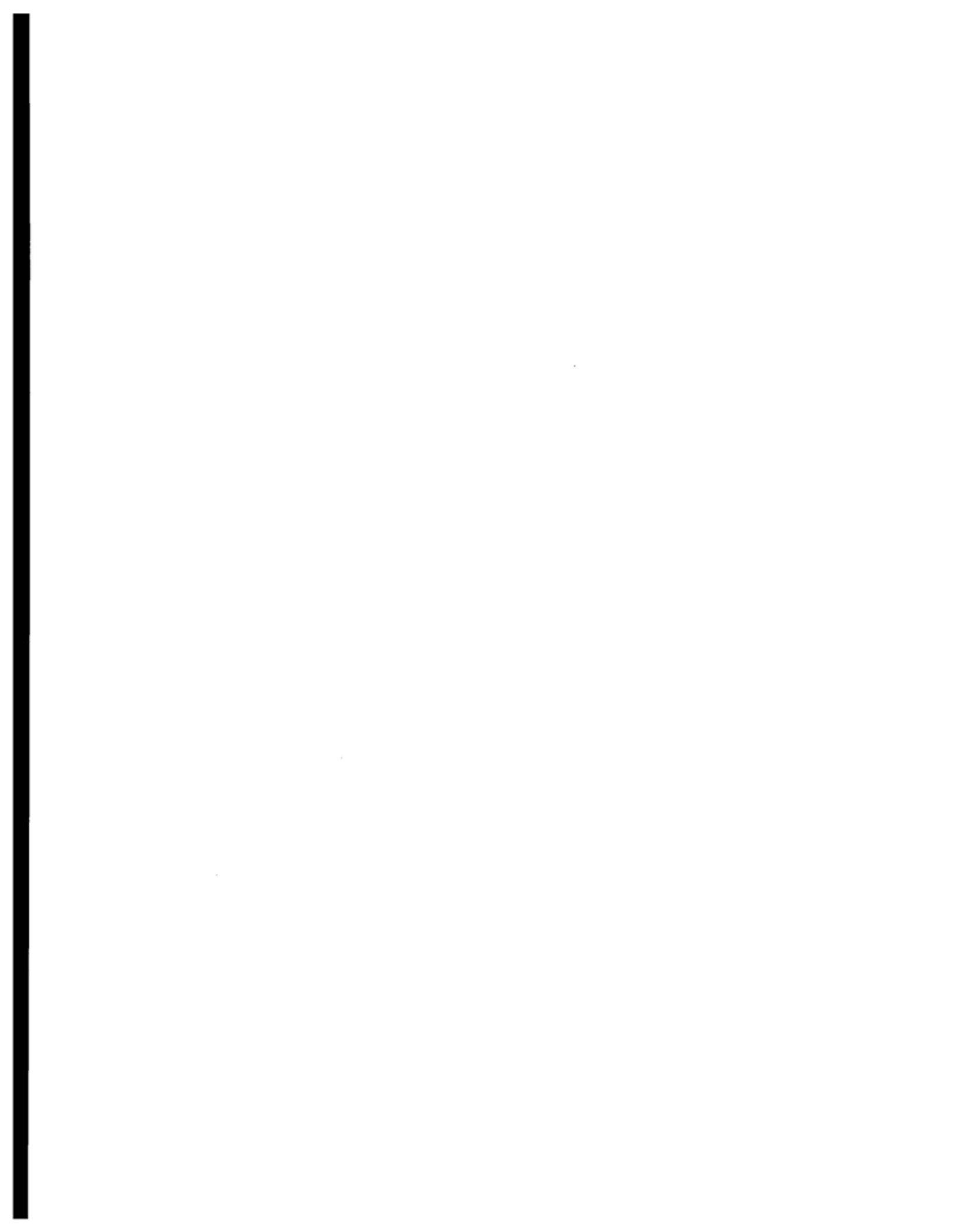
SUBMERGED RESOURCES CENTER PROFESSIONAL REPORTS

1. Daniel J. Lenihan, Toni L. Carrell, Stephen Fosberg, Larry Murphy, Sandra L. Rayl and John A. Ware. *Final Report of the National Reservoir Inundation Study*. Two volumes. Submerged Cultural Resources Unit, 1981.
2. Larry E. Murphy, Editor. *Submerged Cultural Resources Survey: Portions of Point Reyes National Seashore and Point Reyes-Farallon Islands National Marine Sanctuary*. Submerged Cultural Resources Unit, 1984. Originally published as Southwest Cultural Resources Center Professional Papers #1.
3. Toni Carrell. *Submerged Cultural Resources Inventory: Portions of Point Reyes National Seashore and Point Reyes-Farallon Islands National Marine Sanctuary*. Submerged Cultural Resources Unit, 1984. Originally published as Southwest Cultural Resources Center Professional Papers #2.
4. Toni Carrell. *Submerged Cultural Resources Site Report: NOQUEBAY, Apostle Islands National Lakeshore*. Submerged Cultural Resources Unit, 1985. Originally published as

Southwest Cultural Resources Center Professional Papers #7.

5. Daniel J. Lenihan, Editor. *Submerged Cultural Resources Study: Isle Royale National Park*. Submerged Cultural Resources Unit, 1987. Originally published as Southwest Cultural Resources Center Professional Papers #8.
6. Toni Carrell, Editor. *Submerged Cultural Resources Site Report: Charles H. Spencer Mining Operation and Paddle Wheel Steamboat, Glen Canyon National Recreation Area*. Submerged Cultural Resources Unit, 1987. Originally published as Southwest Cultural Resources Center Professional Papers #13.
7. James P. Delgado and Stephen A. Haller. *Submerged Cultural Resources Assessment: Golden Gate National Recreation Area, Gulf of the Farallones National Marine Sanctuary and Point Reyes National Seashore*. Submerged Cultural Resources Unit, 1989. Originally published as Southwest Cultural Resources Center Professional Papers #18.
8. C. Patrick Labadie. *Submerged Cultural Resources Study: Pictured Rocks National Lakeshore*. Submerged Cultural Resources Unit, 1989. Originally published as Southwest Cultural Resources Center Professional Papers #22.
9. Daniel J. Lenihan, Editor. *Submerged Cultural Resources Study: USS Arizona Memorial and Pearl Harbor National Historic Landmark*. Submerged Cultural Resources Unit, 1989. Originally published as Southwest Cultural Resources Center Professional Papers #23.

10. Toni L. Carrell, Editor. *Submerged Cultural Resources Assessment of Micronesia*. Submerged Cultural Resources Unit, 1991. Originally published as Southwest Cultural Resources Center Professional Papers #36.
11. James P. Delgado, Daniel J. Lenihan and Larry Murphy. *The Archeology of the Atomic Bomb: A Submerged Cultural Resources Assessment of the Sunken Fleet of Operation Crossroads at Bikini and Kwajalein Atoll Lagoons, Republic of the Marshall Islands*. Submerged Cultural Resources Unit, 1991. Originally published as Southwest Cultural Resources Center Professional Papers #37.
12. Larry E. Murphy. *SSL17: Natural Site-Formation Processes of a Multiple-Component Underwater Site in Florida*. Submerged Cultural Resources Unit, 1990. Originally published as Southwest Cultural Resources Center Professional Papers #39.
13. Larry Murphy, Editor. *Dry Tortugas National Park, Submerged Cultural Resources Assessment*. Submerged Cultural Resources Unit, 1993. Originally published as Southwest Cultural Resources Center Professional Papers #45.
14. Don Morris and James Lima. *Channel Islands National Park and Channel Islands National Marine Sanctuary, Submerged Cultural Resources Assessment*. Submerged Cultural Resources Unit, 1996. Originally published as Intermountain Cultural Resource Centers Professional Papers #56.
15. Larry E. Murphy, Editor. *H.L. Hunley Site Assessment*. Submerged Cultural Resources Unit, 1998. Originally published as Cultural Resources Management Professional Papers #62.
16. James E. Bradford, Matthew A. Russell, Larry E. Murphy and Timothy G. Smith. *Yellowstone National Park Submerged Resources Survey*. Submerged Resources Center, 2003. Cultural Resources Management Professional Papers #65.
17. Matthew A. Russell. *Comet Submerged Cultural Resources Site Report*. Submerged Resources Center Professional Report #17, 2004.
18. Matthew A. Russell. *Beached Shipwreck Archeology: Case Studies from Channel Islands National Park*. Submerged Resources Center Professional Report #18, 2005.
19. David L. Conlin, editor. *USS Housatonic Site Assessment*. Submerged Resources Center Professional Report #19, 2005.



UNDERWATER ARCHAEOLOGICAL BRANCH PROFESSIONAL REPORTS

1. Donny L. Hamilton. *Basic Methods of Conserving Underwater Archaeological Material Culture*, 1996. Underwater Archaeological Branch, Naval Historical Center, Washington, DC.

2. W. Wilson West, Jr. *USS Tecumseh Shipwreck Management Plan*, 1997. Underwater Archaeological Branch, Naval Historical Center, Washington, DC.

3. Robert S. Neyland and Barbara Voulgaris. *The Boca Chica Channel Wreck: A Site Assessment*, 2003. Underwater Archaeological Branch, Naval Historical Center, Washington, DC.

4. David L. Conlin, Editor. *USS Housatonic Site Assessment*, 2005. Underwater Archaeological Branch, Naval Historical Center, Washington, DC.

Mission: As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally-owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and work to assure that their development is in the best interests of all our people. The Department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under US Administration.