OCS Study
BOEMRE 2011-003

Impact of Recent Hurricane Activity on Historic Shipwrecks in the Gulf of Mexico Outer Continental Shelf

U.S. Department of the Interior
Bureau of Ocean Energy Management, Regulation and Enforcement
Gulf of Mexico OCS Region

OCS Study
BOEMRE 2011-003

Impacts of Recent Hurricane Activity on Historic Shipwrecks in the Gulf of Mexico Outer Continental Shelf

Authors

Robert Gearhart II
Doug Jones
Amy Borgens
Sara Laurence
Todd DeMunda
Julie Shipp

Prepared under BOEMRE Contract
M07PC13010
by
PBS&J
6504 Bridge Point Parkway
Suite 200
Austin, Texas 78730

Published by

U.S. Department of the Interior
Bureau of Ocean Energy Management, Regulation and Enforcement
Gulf of Mexico OCS Region

New Orleans
June 2011

DISCLAIMER

REPORT AVAILABILITY

This report is available only in compact disc format from the Bureau of Ocean Energy Management, Regulation and Enforcement, Gulf of Mexico OCS Region, at a charge of $15.00, by referencing OCS Study BOEMRE 2011-003. The report may be downloaded from the BOEMRE website through the Environmental Studies Program Information System (ESPIS). You will be able to obtain this report also from the National Technical Information Service in the near future. Here are the addresses. You may also inspect copies at selected Federal Depository Libraries.

U.S. Department of the Interior
Bureau of Ocean Energy Management,
Regulation and Enforcement
Gulf of Mexico OCS Region
Public Information Office (MS 5034)
1201 Elmwood Park Boulevard
New Orleans, Louisiana 70123-2394
Telephone requests may be placed at
(504) 736-2519, 1-800-200-GULF, or
Rush Orders: 1-800-553-6847
Fax: (504) 736-2620

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161
Phone: (703) 605-6040
Fax: (703) 605-6900
Email: bookstore@ntis.gov

CITATION

Gearhart, II, R., D. Jones, A. Borgens, S. Laurence, T. DeMunda, and J. Shipp. 2011. Impacts of recent hurricane activity on historic shipwrecks in the Gulf of Mexico Outer Continental Shelf. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation and Enforcement, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study BOEMRE 2011-003. 202 pp.

ABOUT THE COVER

Cover image of Hurricane Katrina, courtesy of National Oceanic and Atmospheric Administration:

http://www.katrina.noaa.gov/satellite/satellite.html

ACKNOWLEDGMENTS

PBS&J would like to thank several individuals for their contributions to the completion of this project. First and foremost, we would like to thank the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) for the opportunity to conduct this study, and especially Dave Ball, Chris Horrell, and Jack Irion for their support and cooperation.

Additional thanks are due to Dave, Chris, and Herb Leedy (BOEMRE divers) for their assistance with fieldwork tasks; Paul Sjordal, Mark Henry, Roger Lackey, and Dan Hudson (PBS&J divers); Ken Bush and Sharon Cain of *Fling* Charters, and the rest of the *Fling* crew including Captain Bland Ellan, dive masters John, Dibble, and Mike, and cook, Riley; Chris Killilay (National Archives, Washington, D.C.), Claudia Jew (Mariners' Museum), and the staff of the Steamship Historical Society for their invaluable archival research assistance; Linda Nance for report editing; Chris Vidrick and Bob Bryant for word processing and report formatting; Kim Griffin for report production; Bill Hailey for the cover graphics; PBS&J scientists Robert Rogers and Kathy Ketteridge for their respective contributions to the sedimentology and oceanographic modeling portions of this report; and finally to the members of *Gentlemen of Fortune*, Avery Munson, Gary and Renée Hebert, and Craig DeRouen for their eager cooperation and southern hospitality.

Robert Gearhart served as the archaeological Principal Investigator for this study. Doug Jones, Amy Borgens, and Sara Laurence contributed analysis of the remote-sensing and archaeological diving results, archival research, and documentation of *New York*'s artifacts. Todd DeMunda performed the oceanographic wave-current interaction modeling, and Julie Shipp conducted the box core particle-size analysis. Dr. Kathryn Ketteridge and Robert Rogers provided scientific oversight for the oceanography and sedimentology tasks, respectively.

ABSTRACT

In 2005 the Gulf of Mexico was significantly impacted by Hurricanes Katrina and Rita, two of the costliest hurricanes in U.S. history. Combined, these storms destroyed over 100 offshore oil and gas platforms and damaged more than 500 pipeline segments. The extent of this damage raised concerns within BOEMRE's Historic Preservation Program regarding the potential effects to Gulf of Mexico shipwrecks that were subjected to the same destructive forces.

Ten wrecks were selected for investigation based on their proximity to the hurricane paths and on the availability of prestorm archaeological data. Each of these wrecks was subjected to a remote-sensing survey, and based on those results, four of the wrecks were selected for further investigation by divers in order to quantify the extents of storm-induced damage. When possible, box core sediment samples were collected and analyzed in order to characterize the marine sediments at each site. Previously published hindcast environmental data were further used to produce wave-current interaction models of the horizontal and vertical forces exerted on each of the four wrecks during peak-storm conditions. Archaeological and historical knowledge of the wrecks was supplemented by additional archival research, and, in the case of the wreck of *New York*, documentation of artifacts recovered by a private salvage operation.

Quantifiable hurricane impacts varied widely among the four investigated wrecks, despite wave-current interaction models that illustrated consistently severe environmental conditions at each site. Two wrecks exhibited no discernible effects, and the combined data were at best inconclusive. Conversely, a third site was heavily impacted by bottom currents that resulted in significant hull collapse. The fourth site was not negatively affected by the hurricane forces, but was instead returned to a protective anaerobic environment due to complete reburial. These results differ significantly from documented hurricane impacts to wrecks sunk as artificial reefs in other regions of the U.S. The authors hypothesize that this discrepancy may be caused by an inverse relationship between the age of a shipwreck (i.e., the number of hurricanes it has been subjected to over time) and the damage caused by each subsequent hurricane event.

CONTENTS

Page

Page

APPENDICES

LIST OF FIGURES

Page

LIST OF TABLES

Page

1.0 INTRODUCTION

Within a four-week period in the second half of 2005, the Gulf of Mexico (GOM) was significantly impacted by two major hurricanes, Katrina and Rita. Hurricane Katrina is considered the costliest and one of the deadliest hurricanes ever to strike the United States coast. Though the storm was a Category 3 hurricane when it made landfall, it had reached Category 5 intensity when centered 196 miles (mi) (315 kilometers [km]) southeast of the Mississippi River mouth. At its peak, the storm had maximum sustained wind speeds of 173 miles per hour (mph) (77.3 meters per second [m/s]) extending over an area 30 mi (48.3 km) in diameter (Figure 1), and a central pressure of 902 millibars (mb). At the time, this was the fourth lowest central pressure on record for any hurricane in the Atlantic Basin. A National Data Buoy Center (NDBC) buoy located approximately 65 mi (105 km) south of Dauphin Island, Alabama, registered an estimated maximum wave height of 105 feet (ft) (32 meters [m]), with sustained seas over 12 ft (3.7 m) for 47 hours. At the time of peak wave height, the eye of the storm was approximately 73 mi (117 km) west of the buoy.

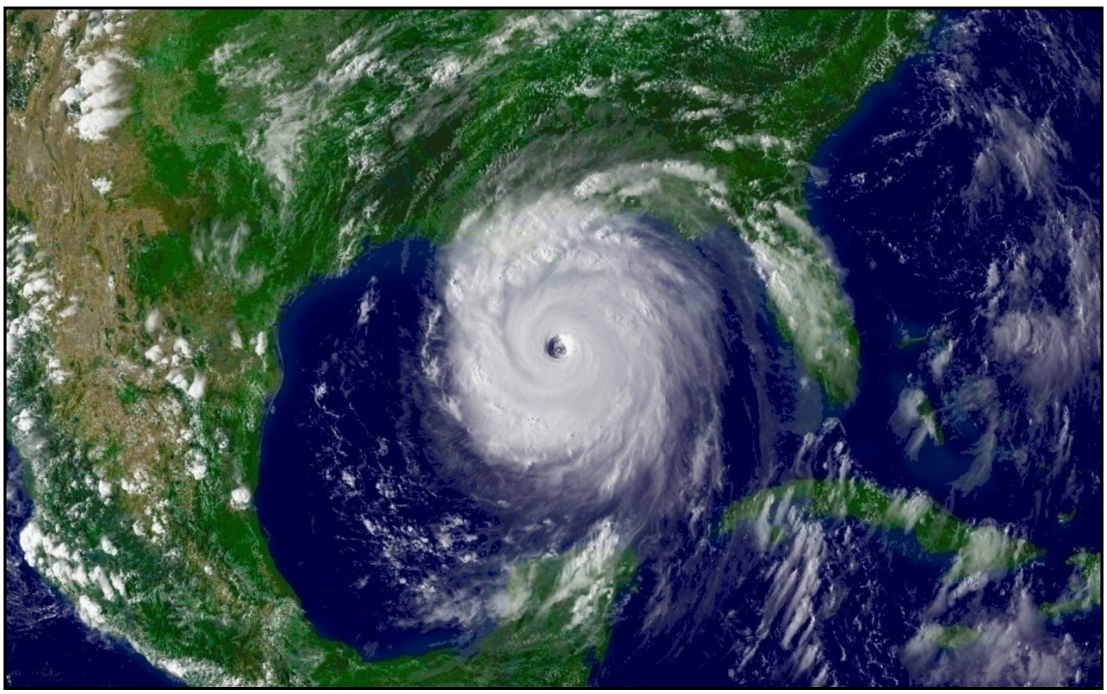


Figure 1. Hurricane Katrina, August 28, 2005 (Image courtesy of the National Oceanic and Atmospheric Administration (NOAA), http://www.noaanews.noaa.gov/stories2009/20090715_ fltipsheet.html).

Similarly, Hurricane Rita maintained Category 5 intensity for about 18 hours, reaching peak sustained winds of 178 mph (79.6 m/s) when 311 mi (500 km) south-southwest of the Mississippi River mouth (Figure 2). It had a minimum central pressure of 897 mb, which surpassed Katrina for the fourth lowest central pressure on record in the Atlantic Basin. An NDBC buoy located approximately 22 mi (35 km) east of Galveston registered an estimated maximum wave height of 38 ft (11.6 m) when the eye of Rita was approximately 47 mi (76 km) east of the buoy.

Figure 2. Hurricane Rita, September 25, 2005 (Image courtesy of NOAA, http://www.nnvl.noaa.gov/cgi-bin/index.cgi?page=items&ser=109799).

Not surprisingly, the massive forces associated with these storms left a wide path of destruction and devastation, not only in the coastal areas where they made landfall, but also on and beneath the waters of the GOM. The combined wrath of Katrina and Rita destroyed over 100 offshore oil and gas platforms and jackup rigs, and damaged more than 500 pipeline segments (Det Norske Veritas [DNV] 2007:45). Damage to surface structures exposed to such conditions was to be expected. Significant impacts to submerged and relatively low-profile pipelines, however, were somewhat more surprising. For example, a 27-mi (43.5-km) segment of 18-inch-diameter (45.7-centimeter [cm]) pipe at a depth of 209 ft (63.7 m) experienced a maximum lateral displacement of 3,000 ft (914 m) when subjected to a significant wave height of 38 ft (11.6 m) (DNV 2007:51).

The magnitude of this pipeline damage raised questions within the Bureau of Ocean Energy Management, Regulation and Enforcement's (BOEMRE) Historic Preservation Program regarding the potential environmental effects to shipwrecks lying on or embedded in the seabed when storms of such magnitude pass nearby. Evidence from pipeline damage reports and storm track records suggests that many historic shipwrecks on the GOM Continental Shelf have been affected to some degree by multiple hurricanes. To what extent have these hurricanes played a role in the formation and evolution of shipwreck sites?

In response to the destructive forces of these two Category 5 hurricanes, BOEMRE allocated over $1.5 million through their Environmental Studies Program to conduct research on the impacts of these storms on natural and cultural resources. In January 2007, BOEMRE contracted PBS&J of Austin, Texas, to assess the impacts of recent hurricane activity on selected historic shipwrecks in the GOM.

1.1 Study Objectives

BOEMRE, an agency of the U.S. Department of the Interior, is tasked by Section 106 of the National Historic Preservation Act to take into account the effects of their undertakings, including their permitted actions, on historic properties. This study supports that mission by providing a baseline for expectations regarding hurricane damage of shipwrecks against which anthropogenic damage associated with oil and gas activity can be measured.

PBS&J was contracted to investigate six wreck sites. In actuality, a total of ten sites were surveyed, including a follow-up diver assessment of four shipwrecks that had been documented by sonar survey and/or by diver visual inspection sometime prior to the passage of Hurricanes Katrina and Rita. Prestorm baseline conditions for each of these four sites were established through review of published literature concerning archaeology, geology, sediments, and oceanography. Peak storm environmental conditions at each site were modeled from published wave and current data for Katrina and Rita. Poststorm conditions were determined by conducting a remote-sensing survey and subsequent archaeological diver investigation of each wreck.

The specific objectives of this study were to: (1) conduct remote-sensing surveys in order to document the macro-scale poststorm condition of the sites; (2) compare and contrast pre- and poststorm remote-sensing data from each site; (3) carry out diver investigations of selected sites to document areas that had changed during the period between pre- and poststorm surveys; (4) collect sedimentary samples in order to characterize the substrate; (5) estimate peak storm conditions on the seafloor at each site based on wave-current interaction models; and (6) conduct archival and historical research of the primary study sites to fill gaps in their histories. Shipwrecks were selected for study based on the following criteria: they had to be less than 130 ft (39.6 m) deep in order to permit scientific diving; each had to have been imaged by side-scan sonar prior to Katrina and Rita; and they had to be located less than 75 mi (121 km) from the eye of either storm.

1.2 Location of the Study

The scope of work originally proposed assessing hurricane damage of six shipwreck sites. Based on discussions at the contract kickoff meeting, the list of study wrecks (Table 1) was revised to include five high-priority wrecks (proposed for dive investigations) and four secondary study sites in case geophysical survey results indicated that one or more of the high-priority sites was unsuitable for the purposes of the study. Three alternative study sites were added to the survey plan, and one primary site, Site 15306, was removed from the primary (diving) list during fieldwork based on discussions with BOEMRE. During the remote-sensing survey cruise in May 2007, two secondary sites, *Wagon Train* and *Caribe No. 500*, were removed from the study list, following consultation with BOEMRE. As a result, a total of 10 sites were visited by PBS&J during the posthurricane geophysical survey (Table 1 and Figure 3). Four of those sites (referred to as the primary study sites) (Table 1), were also subjected to dive investigations.

Table 1

Shipwrecks Selected for Study

Name	Lease Block Area	Hurricane Proximity
**New York*	High Island	34.4 mi (55.4 km) West of Rita
**Gulf Tide*	West Cameron	8.4 mi (13.5 km) West of Rita
*Site 323	East Cameron	28.5 mi (45.9 km) East of Rita
**Castine*	Grand Isle	30.4 mi (48.9 km) West of Katrina
**Site 15306	Vermillion	37.5 mi (60.4 km) East of Rita
***R.M. Parker Jr.*	South Timbalier	69.6 mi (112.0 km) West of Katrina
***Sheherazade*	Eugene Island	82.6 mi (133.0 km) East of Rita
**Site 389	South Timbalier	63.3 mi (101.9 km) West of Katrina
**Site 343	High Island	23.4 mi (37.6 km) West of Rita
**USS *Hatteras*	Galveston	77.7 mi (125.0 km) West of Rita
****Wagon Train*	Eugene Island	78.3 mi (125.9 km) East of Rita
****Caribe No. 500*	Eugene Island	77.2 mi (124.3 km) East of Rita

* Primary study sites (geophysical survey and diving).
** Secondary study sites; geophysical survey only.
*** Not visited; removed from study list during survey trip.

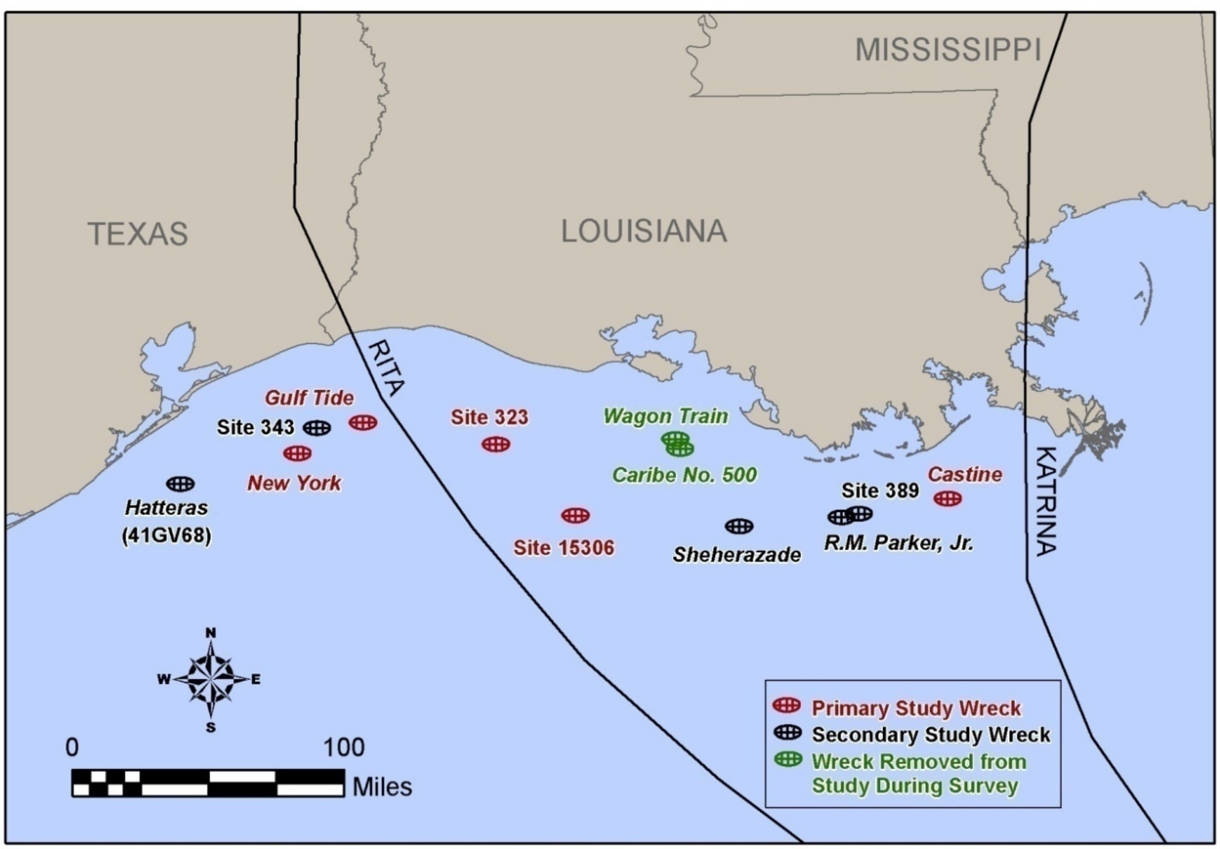


Figure 3. Wreck locations.

Although this study focused on the effect of hurricanes Katrina and Rita on historic shipwrecks, this topic has implications for the entire Continental Shelf in the GOM, as well as for other shallow areas affected by tropical weather. Throughout this report any reference to the Continental Shelf refers to the actual geophysical feature by that name, rather than to the larger geo-political region known as the Outer Continental Shelf (OCS). The OCS includes the seafloor lying between the seaward extent of the States' jurisdiction and the seaward extent of Federal jurisdiction and includes substantial deepwater areas. The seaward margin of the Continental Shelf (i.e., the top of the Continental Slope) in the GOM occurs at a depth of about 590 ft (180 m). The effects of hurricanes upon the seafloor, however, are limited to the actual Continental Shelf at depths of less than approximately 300 ft (91 m). Mention in this report of the shallow Continental Shelf refers to that portion of the shelf that is less than 300 ft (91 m) deep.

1.3 Scope of Investigations

With this study, BOEMRE sought a multidisciplinary approach to site interpretation, utilizing a combination of archaeology, sediment analysis, and oceanographic wave modeling. This research design was intended both to quantify hurricane damage to sites, and, in a broader sense, to use that information as an analytical tool to differentiate between natural and anthropogenic impacts on other GOM wrecks, particularly those impacts associated with the petroleum and commercial fishing industries. Each of the selected sites was evaluated based on the combined analysis of their prestorm, peakstorm, and poststorm conditions.

The level of prestorm knowledge varied significantly from one site to the next. In every case, side-scan sonar imagery predated the hurricanes, although the quality of this imagery was not always adequate for accurate analysis. All but two sites, 389 and 343, were visited by archaeological divers prior to the hurricanes; however, in all cases the extents of site documentation varied.

Over the duration of this study, prestorm baseline site information was collected relating to archaeology, history, hurricanes, sediments, geology, oceanography, pipeline damage reports, and artificial reef damage reports. Much of this information is of a general nature relevant to broad expanses of the GOM, while other sources are specific to the study sites. Examples of anthropogenic damage to wrecks were also collected in order to compare and contrast these with hurricane damage.

Peak storm conditions at each site were modeled using hindcast predictions of wave height and bottom surge currents, based upon storm conditions recorded at weather buoys that geographically bracket the study sites (Oceanweather, Inc. 2006). Characterizations of storm effects on study sites were supplemented where possible by reports of damage to nearby pipelines. These environmental data were combined with archaeological data to produce a site-specific oceanographic wave-current interaction model that quantified peak storm waves relative to wreck orientations, wave particle velocity ranges, and duration of individual storm wave interaction with each site.

A combination of methods, including magnetometer and side-scan sonar survey, diver examination of shipwrecks, and analysis of sediment cores was used to document the poststorm condition of each site. Poststorm site maps were prepared based on side-scan and sector-scan sonar imagery, magnetometer data, and diver observations, and then compared with prestorm site data acquired from BOEMRE files and published studies.

Archaeological site investigations were divided between two separate field cruises in 2007. The remote-sensing survey was conducted over four days in May 2007. Following analysis of the geophysical data and coordination of diving objectives, the diver investigation of selected sites was performed over 10 days in October 2007. Collection of sediment cores was conducted concurrent with the archaeological diving.

A total of 10 sites were surveyed during the May 2007 remote-sensing cruise. These included the five sites initially selected by BOEMRE as high-priority targets, two of the sites selected as secondary targets, and three sites added to the survey plan during the fieldwork. A separate field decision was made in consultation with the BOEMRE Contracting Officer's Technical Representative (COTR) to exclude the remaining two secondary wrecks, *Caribe 500* and *Wagon Train*, from further study. This decision was based on a number of factors, including the fact that survey data up to that point demonstrated an apparently minimal effect of the storms on other study sites that were located much closer to storm paths than were either of the excluded sites.

Brief reconnaissance level surveys, consisting of limited side-scan sonar passes, were conducted at three wreck sites that were not on the initial project list. These three sites included Site 389 (possibly *J.A. Bisso*), Site 343, and Site 236 (USS *Hatteras*). These surveys were of limited duration; an opportunity presented itself to visit these three sites because they were situated near the paths of travel between higher-priority study sites. The decision to conduct these additional surveys was made in consultation with the COTR.

Analysis of the pre- and poststorm sonar data at the 10 sites indicated possible storm damage to three of the five high-priority sites, including Site 323 and the dredge *Gulf Tide* (the two closest to Hurricane Rita's track), and the wood-hulled wreck of the steamship *New York*. Those three sites were selected for diver investigation during the October 2007 cruise, along with USS *Castine,* which was selected because it was the closest study site to Hurricane Katrina's path (Gearhart 2007a). There had been no apparent change to Site 15306 or to the secondary study sites; therefore, given their relatively greater distance from storm tracks than the primary wrecks, no further investigation was recommended. Table 2 presents a synopsis of remote-sensing results and recommendations for each site.

Priorities for diver assessments were determined in part by the types and quality of prestorm data available. The purpose of these investigations was to clarify the remote-sensing data and to document current site conditions to the extent they indicated the presence or absence of poststorm impacts. Further objectives were to determine the identity of Site 323 based on site characteristics and to confirm the suspected identification of the West Cameron–area wreck as *Gulf Tide*, a mid-twentieth-century dredge boat. Finally, each site was to be evaluated for its eligibility for listing on the National Register of Historic Places (NRHP).

Table 2

Postsurvey Damage Assessment and Recommendations

Name	Damage	Recommendations
New York	Increased exposure; reports of salvage activity	Diving to document extent of storm damage and salvage
Gulf Tide	Possibly increased exposure, but earlier sonar imagery of poor quality	Diving to document extent of storm damage
Site 323	Significant hull breakage near stern	Diving to document extent of storm damage
Castine	No apparent change	This is the closest wreck to Hurricane Katrina, so even though no gross change is apparent from new sonar imagery, diving is recommended
Site 15306	No apparent change	No further investigation
R.M. Parker Jr.	No apparent change	No further investigation
Sheherazade	No apparent change	No further investigation
Site 389	No apparent change	No further investigation
Site 343	Assessment of storm damage complicated by poor quality of earlier sonar imagery	No further investigation unless sufficient previous data exist to allow meaningful comparisons
USS *Hatteras*	No apparent change	No further investigation

Following completion of the fieldwork, BOEMRE issued a contract modification for additional archival research on the four primary study wrecks selected for diver investigation. This research was intended to supplement the baseline archaeological knowledge of each vessel by acquiring as much information as possible on the vessels' hull construction details, use histories, and wrecking events. The scope of research included a trip to the Mariners' Museum in Newport News, Virginia, the Library of Congress, and National Archives branches in Washington, D.C., and College Park, Maryland. Documents researched included various collections of ship plans, drawings, photographs, vessel papers, insurance records, registers and enrollments, and newspaper archives. At the request of BOEMRE, additional time was devoted to researching several reported but not yet discovered GOM shipwrecks that were not included in the hurricane impacts study. This research was intended to locate information that would fill in gaps in the reported vessel information and potentially assist in the wrecks' eventual discovery and identification.

Finally, a second contract modification was issued for inventorying and cataloging artifacts recovered from the wreck of *New York*. The salvage group *Gentlemen of Fortune*, who initially discovered the wreck in 1990, have been conducting periodic excavations of the site since 1994, including one that ended only a few days prior to PBS&J's arrival during the October 2007 dive cruise. *Gentlemen of Fortune* had previously filed a civil claim for salvage rights in U.S. District Court, on August 31, 2006 (U.S. District Court, Western District of Louisiana, Lafayette-Opelousas Division 2006). This claim was granted on February 2, 2007 (U.S. District Court, Western District of Louisiana, Lafayette-Opelousas Division 2007). In December 2008, *Gentlemen of Fortune* invited PBS&J to their facilities in New Iberia, Louisiana, to examine the artifact assemblage and provide guidance on proper conservation methods.

This report is divided into six chapters. Chapter 2 examines the magnitudes of Hurricanes Katrina and Rita relative to other hurricanes in the GOM, and also discusses previously studied effects of hurricanes on petroleum industry infrastructure and vessels sunk as artificial reefs. Chapter 3 presents the methodology and results of the wave-current interaction model and hydrodynamic analysis of peak-storm site conditions. Chapter 4 presents the results of the historical/archival research, remote-sensing survey, diver investigation, sediment analysis, hurricane impact assessment, and NRHP assessment for each of the four primary study sites. A discussion of conclusions follows in Chapter 5, including a discussion of potential direct and indirect effects of hurricanes on historic shipwrecks and an analysis of this study's results compared with previous studies of hurricane effects on wrecks sunk as artificial reefs. Bibliographic references are listed in Chapter 6, and supplementary information is appended to the end of the report. Appendix A presents the remote-sensing survey results for the six secondary wrecks not selected for diver investigation as well as an analysis of posthurricane remote-sensing data collected by BOEMRE on the steamboat *Josephine*. Additional archival research results for GOM shipwrecks not included in the hurricane impact study are provided in Appendix B. A discussion and catalog of artifacts recovered from *New York* by *Gentlemen of Fortune* is presented in Appendix C, and a history of tropical storms potentially affecting the four primary study sites is provided as Appendix D.

2.0 HURRICANE IMPACTS TO ARTIFICIAL REEF WRECKS AND SUBMERGED PIPELINES

Hurricanes are the most severe weather events to regularly affect the GOM, and have been responsible for an untold number of shipping losses. Throughout history, a large number of hurricanes have passed through the GOM, yet their effect upon the site formation processes of sunken ships is poorly understood. It is probable that such storms have played a central role in the degradation of shipwrecks. But as wrecks break down and disperse through a combination of chemical and physical processes, hurricanes might also play a key role in preserving the remaining material through burial.

Quantifying the effects of storms upon shipwrecks is a difficult task. A comprehensive study of this topic would require long-term monitoring of several sunken vessels representative of different hull types, construction materials, water depths and substrate materials. One would need to conduct field visits to each site at regular intervals. This would include a site visit soon after a storm passes near each wreck in order to establish a baseline from which to measure storm damage and to differentiate hurricane effects from structural collapse caused by the long-term degradation of chemical and biological processes. The financial resources and time required for such an approach would be prohibitive.

The approach of the present study relies upon the body of previous archaeological research conducted in the GOM as the source of baseline (prestorm) observations, thereby limiting the expense to poststorm observations and analysis. The timing of the study, following Katrina and Rita, two of the largest storms ever recorded in the GOM, offered the possibility of making poststorm observations on several shipwrecks in a coordinated research effort. Unfortunately, there are only a small number of shipwrecks near the path of either Katrina or Rita for which adequate prestorm data exist, and the types and quality of prestorm data limit the conclusions one can draw regarding the effects of storms on shipwrecks. Therefore, it is instructive to look elsewhere for parallel examples of the damages inflicted on shipwrecks by hurricanes.

2.1 Effects of Hurricanes on Vessels Sunk as Artificial Reefs

The most abundant documentation of hurricane damage to sunken ships comes from diver accounts of vessels sunk as artificial reefs. Artificial reef wrecks are frequently visited by sport divers, so damage resulting from a single storm is quickly observed and often documented in some fashion. All of the states bordering the GOM have government-sponsored programs to promote the development of artificial reefs. The Gulf States Marine Fisheries Commission (GSMFC), founded in 1949 by joint agreement of all five states bordering the GOM, "has as its principal objective the conservation, development, and full utilization of the fishery resources of the Gulf of Mexico. . . ." (Gulf States Marine Fisheries Commission 2008). The intentional sinking of ships accounts for about 25 percent of all artificial reefs in the GOM (Gregg and Murphey 1994). The first systematic use of ships to create artificial reefs in the GOM was the sinking of 26 Liberty ships off four Gulf states during the 1970s. These Liberty ships were obsolete World War II–era vessels acquired from the U.S. Maritime Administration's reserve fleet.

In 1997, the Artificial Reef Subcommittee of the GSMFC compiled a document titled *Guidelines for Marine Artificial Reef Materials* to provide a comprehensive discussion of the various materials commonly used to create artificial reefs, including detailed information regarding the use of sunken vessels for that purpose. The second edition of the GSMFC guidelines (Lukens and Selberg 2004) was updated, reorganized, and illustrated in collaboration with the Atlantic States Marine Fisheries Commission. The purpose of the report was to assist states with selecting materials for artificial reef construction that would best serve the objectives of the Gulf and Atlantic States Marine Fisheries Commissions. The authors focus on the stability and durability of artificial reef materials, including chapters on steel and wooden vessels. The wealth of information in that report regarding the effects of hurricanes on sunken vessels has direct relevance to this study.

Anecdotal information concerning 37 incidents of hurricane damage to artificial reef vessels is summarized in Table 3 for Hurricanes Andrew, Opal, Dennis, Frances, Jeanne, and Ivan. Hurricane damage has been reported in water depths (to top of reef) ranging from 31 to 178 ft (9.4–54.3 m). Several forms of vessel damage have been observed at artificial reefs as described in Table 3 and below. Historic shipwrecks might be affected by storms in any or all of these same ways:

Structural Failure. This is the most common category of damage and includes collapse of major hull structure and/or complete detachment of structural elements from one another (Horn 2005a; Lukens and Selberg 2004; Maher 1996; Pemberton 2005; Turpin and Bortone 2002). At least 28 (65 percent) of the vessels in Table 3 underwent some degree of structural failure. Examples include collapse of outer hulls (especially along broad unsupported spans such as the sides of cargo holds); separation of the pilothouse or other superstructure from the deck; and separation of bow and/or stern from the rest of the hull. Adjectives used to describe such damage in published reports include *ripped*, *torn,* and *twisted*. Large ships were broken into as many as five sections, as was the case with *Antares*.

Lateral Displacement. At least nine vessels in Table 3 experienced measurable displacement ranging from 30 ft (9.1 m) to 1.5 mi (2.4 km). Direction of movement was not always indicated in the source; however, William Horn (2005a:11) stated that vessels move not in the direction of storm surge but in the direction of wave travel. Lukens and Selberg (2004:25) related a story of a 450-ft (137-m) troop ship sunk off the South Carolina Coast that literally bounced across the bottom for a distance of 700 ft (213 m).

Rolling. At least seven vessels in Table 3 experienced a roll displacement during a hurricane. In half of those cases, the rolling was at least partially attributed to scour alongside the hull. The degree of roll varied from a slight list to a full 90 degree roll, as in the well-publicized case of *Spiegel Grove* (Horn 2005b). The ex-USS *Spiegel Grove* was a 510-ft (155-m) LSD (dock landing ship) commissioned for the U.S. Navy in 1956. When *Spiegel Grove* was sunk as an artificial reef in 2002, it inadvertently came to rest on its starboard side in 133 ft (40.5 m) of water. The port side of the ship was only 50 ft (15.2 m) deep when the waves of Hurricane Dennis struck the top of the ship broadside in 2005 and rolled it into a fully upright position. In the process, *Spiegel Grove* settled into a 12-ft-deep (3.7-m) scour that had formed along the west side of the hull.

Vertical Displacement. At least six vessels in Table 3 experienced vertical displacement ranging from 7 to 20 ft (2.1–6.1 m) due to scouring by swift storm currents. In two cases, hulls were cracked and beginning to break apart due to the scouring of sediments from beneath them.

A number of factors affect the stability and structural integrity of vessels deployed as artificial reefs. For example, Lukens and Selberg (2004:34) state that,

Table 3

Hurricane Damage to Steel Vessels Used as Artificial Reefs

Name	Length (ft)	Vessel Type	Reef Age When Damaged (yrs)	Depth (ft)	Vertical Relief (ft)	Wind Speed Estimated at Reef (mph)*	Hurricane	Description of Damage	Source
Almirante	210	freighter	17	125	20	86–121	Andrew	ship turned upside down; 17 years of coral growth scoured off	Lukens and Selberg 2004
Andro	165	freighter	7	105	25	115–173	Andrew	stack damaged; cargo area collapsed; stern section torn off	Lukens and Selberg 2004
Belcher Barge	195	barge	17	57	10	86–121	Andrew	several steel plates torn off barge	Lukens and Selberg 2004
Belzona One	85	tug	2	73	20	109–132	Andrew	wheel house ripped off	Lukens and Selberg 2004
Biscayne	120	freighter	18	60	15	109–132	Andrew	stern section partially separated from main hull by adjacent wreck	Lukens and Selberg 2004
Blue Fire	175	freighter	9	110	20	98–132	Andrew	part of hull and superstructure separated; moved 10 yards; listing	Lukens and Selberg 2004
Concepcion	150	freighter	1	68	20	115–155	Andrew	mid-cargo area collapsed; stern section separated from hull	Lukens and Selberg 2004
C-One	120	Navy tug	2	65	33	115–155	Andrew	hull listing in 10-ft deep scour hole	Lukens and Selberg 2004
Deep Freeze	210	freighter	16	135	30	109–138	Andrew	35 ft of stern section separated from hull	Lukens and Selberg 2004
Doc De Milly	287	freighter	6	150	50	81–104	Andrew	no damage	Lukens and Selberg 2004
Mercedes	250	freighter	7	97	unknown	<81	Andrew	hull broken in 3 places	Lukens and Selberg 2004
Miracle Express	100	freighter	5	60	8	104–132	Andrew	pushed on top of *Biscayne*; hull broken into pieces	Lukens and Selberg 2004

Table 3. Hurricane Damage to Steel Vessels Used as Artificial Reefs (continued).

Name	Length (ft)	Vessel Type	Reef Age When Damaged (yrs)	Depth (ft)	Vertical Relief (ft)	Wind Speed Estimated at Reef (mph)*	Hurricane	Description of Damage	Source
Narwhal	137	freighter	6	115	18	115–155	Andrew	90 percent of structure collapsed; many areas reduced to steel plates on sand	Lukens and Selberg 2004
Noula Express	220	freighter	4	90	unknown	<81	Andrew	hull broken in 3 places	Lukens and Selberg 2004
Orion	118	tug (ship?)	11	95	15	109–132	Andrew	pilothouse ripped from hull	Lukens and Selberg 2004
Police Barge	75	barge	?	55	unknown	unknown	Andrew	moved 75 yards onto concrete reef material; hull has opened up	Lukens and Selberg 2004
Proteus	220	freighter	7	72	18	109–132	Andrew	stern ripped off; remainder of wreck moved 100 yards and is broken up	Lukens and Selberg 2004
Rio Miami	105	tug	3	63	30	109–132	Andrew	settled 20 ft into sand depression	Lukens and Selberg 2004
Shamrock	120	Navy LCI	7	46	15	109–138	Andrew	coral scoured from hull; position and condition unchanged	Lukens and Selberg 2004
Sheri Lyn	235	freighter	5	95	15	104–132	Andrew	50 ft of stern broken off; moved into 105 ft of water	Lukens and Selberg 2004
South Seas	175	yacht	9	65	15	104–132	Andrew	stern broke off; vessel moved 50 ft	Lukens and Selberg 2004
Star Trek	200	freighter	10	210	32	104–132	Andrew	some steel plates torn off; largely intact; same position	Lukens and Selberg 2004
St. Anne D'Auray	110	North Atlantic trawler	6	68	28	104–132	Andrew	intact; unchanged	Lukens and Selberg 2004
Tarpoon	164	coastal freighter	4	65	5	104–132	Andrew	complete destruction	Blair et al. 1994
Tarpoon	165	grain carrier	4	71	5	104–132	Andrew	moved inshore 75 yards; pushed up against natural reefs; hull broke into 3 pieces	Lukens and Selberg 2004

Table 3. Hurricane Damage to Steel Vessels Used as Artificial Reefs (continued).

Name	Length (ft)	Vessel Type	Reef Age When Damaged (yrs)	Depth (ft)	Vertical Relief (ft)	Wind Speed Estimated at Reef (mph)*	Hurricane	Description of Damage	Source
Ultrafreeze	195	freighter	8	118	45	104–132	Andrew	starboard side of hull ripped open; vessel bent amidships at 90-degree angle; pilothouse torn from hull	Lukens and Selberg 2004
Zion Train	164	coastal freighter	1.7	90	35	90–100	Frances	prior to Frances sides had collapsed from offshore passage of Floyd in 2003; Frances detached the bow and moved it 1.3 nm; stern scoured to limestone and moved 7 ft deeper	Horn 2005a
Esso Bonaire	250	petro tanker	15	90	unknown	75–85 (Jeanne); 90–100 (Frances)	Frances/ Jeanne	no obvious damage	Horn 2005a
Gilbert Sea	174	coastal freighter	2.5	89	40	70–75 (Jeanne); 85–100 (Frances)	Frances/ Jeanne	bow broke from the hold and rolled forward and starboard; small holes present in side of hull; sandblasted stern completely separated from hold, rolled backward and to port	Horn 2005a; Pemberton 2005
Miss Jenny	?	barge/dredge	14	90	unknown	75–85 (Jeanne); 90–100 (Frances)	Frances/ Jeanne	no obvious damage	Horn 2005a
Shasha Boekanier	185	coastal freighter	2.6	89	40	70–75 (Jeanne); 85–100 (Frances)	Frances/ Jeanne	entire first hold collapsed to within 3 ft of sand; starboard (south) bulkhead nearly collapsed and stern support inside hull has broken	Horn 2005a; Pemberton 2005

Table 3. Hurricane Damage to Steel Vessels Used as Artificial Reefs (continued).

Name	Length (ft)	Vessel Type	Reef Age When Damaged (yrs)	Depth (ft)	Vertical Relief (ft)	Wind Speed Estimated at Reef (mph)*	Hurricane	Description of Damage	Source
St. Jacques	175	coastal freighter	2.5	89	40	70–75 (Jeanne); 85–100 (Frances)	Frances/ Jeanne	both sides of hold collapsed shoreward (west) and completely broken from stern; both hull bulkheads collapsed to the west	Horn 2005a; Pemberton 2005
Thozina	175	coastal freighter	1.7	89	40	70–75 (Jeanne); 85–100 (Frances)	Frances/ Jeanne	bow is badly broken at the hold and rolled toward shore (west); ship has rolled westward and the stern has broken off completely	Horn 2005a; Pemberton 2005
USS *Muliphen*	459	WWII–era ex-Navy cargo ship	15	184	100	95–100 (Jeanne); 100–105 (Frances)	Frances/ Jeanne	major scour holes at bow and stern; moved 10 ft deeper; bow crack 6 ft wide; bow sagging into scour	Horn 2005a
USS *Rankin*	459	WWII–era ex-Navy cargo ship	16	141	70	90–100 (Jeanne); 100–105 (Frances)	Frances/ Jeanne	ship still lying on starboard side; scouring beneath bow; bow cracking and breaking off from aft hull; torn and twisted forward; port cargo area collapsed; deck torn from hull and lying west of hull; ship moved 10 ft deeper; 10 ft of sand removed from limestone outcrops in scour along east side of hull	Horn 2005a
Antares	387	cargo vessel; in pieces after Opal	9	131	60	121	Ivan	moved sections; turned over stern section that had been upright	Horn 2005a
Belize Queen	86	tug	3	111	35	121	Ivan	moved 180 ft	Horn 2005a
Mohawk Chief	92	tug	1	125	27	121	Ivan	moved 60 ft laterally and 10 ft deeper	Horn 2005a; Horn and Mille 2005
Mariner	68	tug	6	70	15	75–80	Jeanne	no obvious damage	Horn 2005a

Table 3. Hurricane Damage to Steel Vessels Used as Artificial Reefs (continued).

Name	Length (ft)	Vessel Type	Reef Age When Damaged (yrs)	Depth (ft)	Vertical Relief (ft)	Wind Speed Estimated at Reef (mph)*	Hurricane	Description of Damage	Source
Marsha T	64	tug	6	70	15	75–80	Jeanne	moved 903 ft but remained intact and upright	Horn 2005a
Sea Inspector	64	tug	6	70	15	75–80	Jeanne	no obvious damage	Horn 2005a
Antares	387	cargo vessel	7 days	125	60	56–78	Opal	severely damaged; broken into 5 major pieces; reef was only 7 days old when hit	Turpin and Bortone 2002; Maher 1996
Spiegel Grove	510	ex-Navy LSD	3	133	83	unknown	Dennis	rolled 90 degrees from starboard side to upright position; settled in 12-ft-deep scour; waves nearby reported as 15–20 ft	Horn 2005b

*Andrew wind speed estimates based on wind field published by Landsea et al. (2004).
Jeanne wind speed estimates based on wind field published by Wang and Manausa (2005a).
Frances wind speed estimates based on wind field published by Wang and Manausa (2005b).
Opal wind speed estimates based on wind field published by Powell and Houston (1998).

> Susceptibility. . . or resistance to movement is dependent upon a combination of . . . factors [including] . . . depth, extent of vessel surface area exposed to wave energy, vessel orientation with respect to storm direction, wave height, friction forces resisting horizontal movement, . . . the weight of the vessel resisting vertical lift, vertical profile, and localized storm-generated current and surge conditions. Those vessels placed in shallow depths (less than [164 ft] 50 m) are more susceptible to movement during major storm events, such as Category 3–5 hurricanes, than vessels placed at greater depths (Bell and Hall 1994; Blair et al. 1994).

Other factors include the length of time a vessel has been submerged (which relates to the level of corrosion), the type of substrate underlying a vessel, the design of a vessel, its salvage history, and the methods used to sink the ship.

Reef vessels having high vertical profiles and vessels placed at diver-friendly depths are most susceptible to storm damage. Damage to reef vessels resulting from Hurricane Andrew, a Category 5 storm, was extensive:

> Most vessels, which were in 65 to 125 feet [19.8–38.1 m] of water and in the direct path of the hurricane, experienced structural damage. Maximum movement of 700 yards [640 m] was noted for a concrete-loaded steel barge and up to 100 yards [91 m] for a steel freighter. . . . Removal of wheelhouses and stern sections, and hull subsidence into scour depressions were common hurricane effects, when the eye of the hurricane passed nearby. To the north of Dade County . . . 80 miles [129 km] from the hurricane's eye, at least one vessel was moved offsite, four were laid over on their sides, and wrecks in water as deep as 180 feet [54.9 m] experienced hull damage. (Lukens and Selberg 2004:25)

It is clear from reports summarized by Lukens and Selberg (2004) and others that hurricanes are capable of causing substantial damage to steel vessels intentionally sunk as artificial reefs. The degree of damage is not easily predictable because of the number of variables involved; however, it is apparent that damage can occur at depths as great as 200 ft (60 m).

2.2 Effects of Hurricanes on Petroleum Industry Infrastructure

Hurricane impacts to submerged petroleum industry infrastructure, particularly pipelines, provide a further means of comparison relevant to the study of damage to shipwrecks. No effort is made in this report to extrapolate, except in a relative sense, the severity of damage experienced by pipelines to that anticipated for shipwrecks. Rather the level of damage experienced by such structures is witness to the power of such storms.

The combined effects of Hurricanes Katrina and Rita destroyed 109 platforms and 5 rigs, with 3 rigs unaccounted for. The storms damaged another 50 platforms, 19 rigs, and 542 pipeline segments in the GOM (DNV 2007:45). The types of damage most comparable to shipwrecks are from pipelines lying horizontally on the seabed and damaged as a direct result of hurricane-induced bottom currents, as opposed to movement of connected surface platforms or impact from an outside force, such as an anchor drag. A total of 75 pipelines with reported damage from Rita and Katrina appear to have been damaged by bottom currents, including 45 pipelines exposed and/or undermined; 14 pipes ruptured by pulling apart (without any indication of platform damage or outside force); 8 lines laterally displaced over large distances; 7 cases of crossing pipelines damaged due to movement of mats designed to separate the pipes at their intersection; and 1 damaged by a mudflow during Katrina (mudflow damage is more prevalent when storms track east of the Mississippi Delta) (DNV 2007:57–59. The remainder of damage reports concerned pipes, including risers, that may have been damaged due to movement of rigs connected to those pipes or due to outside forces, such as anchors or rigs dragging across them during the storms.

At least one mechanism of pipeline damage is similar to that for hurricane impacts to artificial reef vessels described above; current appears to play a primary role in both instances. Excessive lateral movement of pipelines tends to occur in larger pipes and tends to move in the same direction as maximum bottom currents. For example, a 27-mi (43.5-km) segment of 18-inch (45.7-cm) pipe at a depth of 210 ft (64 m) experienced a maximum lateral displacement of 3,000 ft (914 m) when subjected to a significant wave height of 38 ft (11.7 m) (DNV 2006:51). Movement of pipelines by Hurricane Ivan correlated very closely with areas of maximum hindcast currents (DNV 2006:47), and the direction of lateral pipeline movement was consistent with the direction of hindcast currents (DNV 2006:49). Mudflow damage, likewise, tends to occur to pipelines oriented perpendicular to the maximum current (DNV 2006:29).

Other suspected factors of pipeline damage include failure of pipes intended for self-burial to achieve adequate depth of cover, or prestorm exposure of previously buried pipes over time. Lines that are uncovered for whatever reason might lack sufficient on-bottom stability to resist hurricane forces. Alternatively, buried pipelines might move through failure of weak, silty soils due to pressure waves induced within the seafloor by passing storm waves. Pressure changes in the soil are suspected to change the specific gravity of the mud so that pipes float (DNV 2006:33, 49).

Though pipelines do not serve as a perfect corollary to shipwrecks, the above examples are indicative of the types of stresses that can be inflicted on low-profile objects lying on or just beneath the seafloor during periods of extreme environmental dynamics. Severe wave and current forces are able to induce significant damage to ≤2-ft-diameter (0.6-m) pipelines at considerable depth (relative to storm wave height), and therefore should be expected to produce similar impacts on shipwrecks with much larger surface area and/or eroded and weakened structural elements. When viewed in concert with the documented examples of hurricane damage to artificial reef wrecks, these authors expected to witness similar effects on the wrecks selected for this study.

3.0 PEAK STORM CONDITIONS

The environmental conditions at each of the four primary study sites during the nearest passage of either Hurricane Katrina or Hurricane Rita have been estimated on the basis of hindcast models of each storm produced by Oceanweather, Inc. (2006). Hindcasting in this case is the process of using previously tested mathematical models "to develop a comprehensive, validated and reliable database of wind, sea state, and currents" (Oceanweather, Inc. 2006:1) based on available observations of actual meteorological and oceanographic conditions during the storms. Figures 4 and 5 illustrate the locations of the four primary wrecks with respect to the hindcast wind and wave fields of these storms.

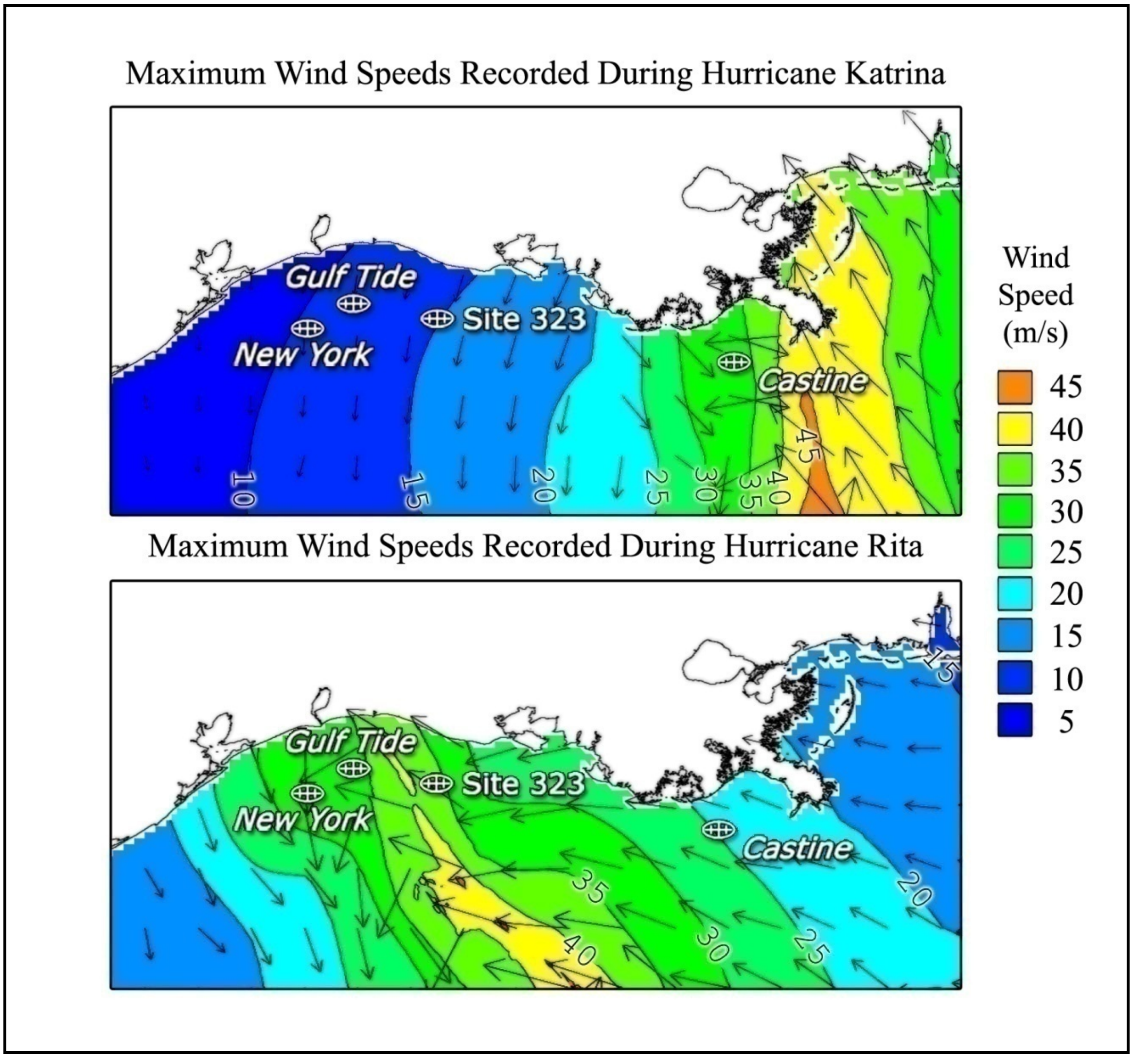


Figure 4. Maximum wind speeds from Oceanweather, Inc. (2006:43). Arrows represent the direction and amplitude of maximum sustained wind speed.

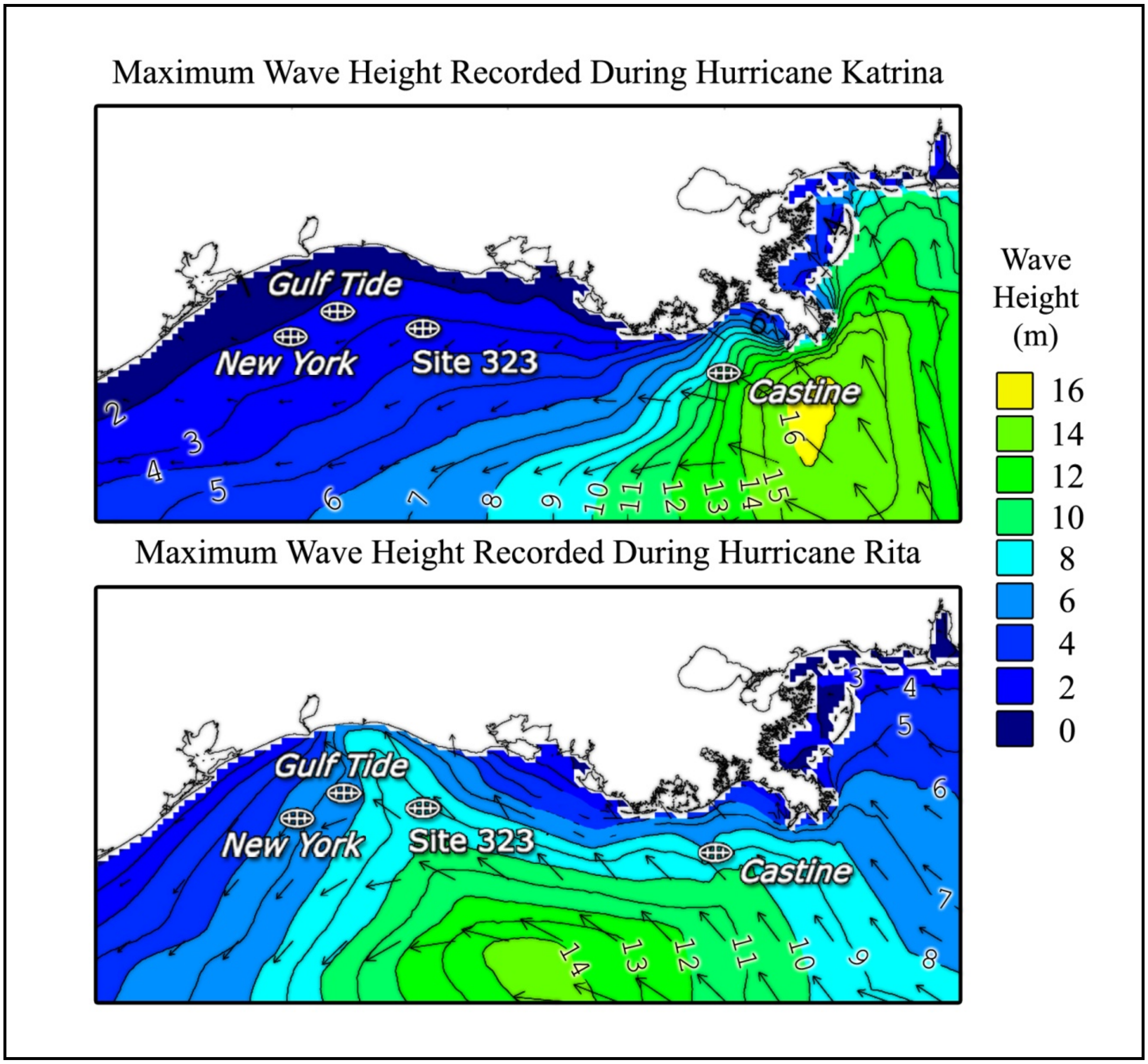


Figure 5. Maximum wave height from Oceanweather, Inc. (2006:44). Arrows represent the direction and amplitude of maximum significant wave height.

Hurricane Katrina passed 30 mi (48 km) east of the ex-USS *Castine* at about 4:00 A.M. on August 29, 2005. At the time, Katrina was a Category 4 storm on the Saffir-Simpson Scale (Table 4) with maximum sustained winds estimated at 136 mph (60.6 m/s) and a significant wave height estimated at 42.7 ft (13.0 m) (U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration [USDOC, NOAA] 2010). Sustained winds over *Castine* were estimated from Oceanweather's hindcast model at 74 mph (32.9 m/s). The maximum significant wave height over *Castine* was estimated at 32 ft (9.8 m). By oceanographic convention, significant wave height is the average wave height (trough to crest) of the largest one-third of waves. Hurricane Rita passed 145 mi (233 km) southwest of *Castine* at about 9:00 A.M. on September 23, 2005, as a very strong Category 3 storm with maximum sustained winds estimated as 130 mph (58.1 m/s). Maximum sustained winds over *Castine* during Rita were roughly 56 mph (25 m/s), although maximum significant wave height was in the 26- to 30-ft (8–9-m) range.

Table 4

Saffir-Simpson Scale of Sustained Wind Speed

Saffir-Simpson Scale Classification	Meters per Second (m/s)	Miles per Hour (mph)
Tropical Storm	18	40
Category 1	33	74
Category 2	43	96
Category 3	50	111
Category 4	59	131
Category 5	70	155

The other three study sites, *New York*, *Gulf Tide*, and Site 323, were affected more severely by Hurricane Rita (see Figures 4 and 5). Hurricane Rita was a Category 3 storm at the time of its nearest approach to *New York*, *Gulf Tide*, and Site 323, with maximum sustained winds of 115–119 mph (51–54 m/s). Maximum significant wave height was estimated at 28.9 ft (8.8 m) abreast of Site 323 at 9:30 P.M. on September 23, 2005. In the short distance Rita traveled from Site 323 until adjacent *Gulf Tide* and *New York*, from 12:30–1:00 A.M. on September 24, the central wave height had decreased to an estimated 23.6 ft (7.2 m). Peak sustained wind speed at Site 323, 29 mi (46.7 km) east of Rita on the strong side of the storm, was estimated at 86 mph (38.4 m/s). The maximum significant wave height was estimated at 30.8 ft (9.4 m). Peak sustained winds over *Gulf Tide*, 8 mi (12.9 km) west of Rita, were estimated at 78 mph (34.9 m/s). Maximum significant wave height at *Gulf Tide* was estimated at 22.6 ft (6.9 m). Peak sustained wind speed at *New York*, 35 mi (56.3 km) west of Rita's path, was estimated at 69 mph (30.9 m/s). Maximum significant wave height at *New York* was estimated at 18.0 ft (5.5 m). Hurricane Katrina's nearest approach to these three sites was 196 mi (315 km) east of Site 323 at about 5:30 A.M. on August 29, 2005. Katrina was a Category 4 storm at the time with peak sustained winds of 131 mph (59 m/s), but maximum sustained winds over Site 323 were only about 34 mph (15 m/s). Maximum significant wave height over the three westernmost sites was in the range of 7–10 ft (2–3 m) during the passage of Katrina.

3.1 Hydrodynamic Analysis

Wave-current interaction models were run at each of the four primary study sites in order to qualitatively assess whether hydrodynamics induced by Hurricanes Katrina and Rita could have caused damage to study shipwrecks. Analysis of waves and currents caused by the hurricanes required acquisition of environmental data for the hurricane periods. These data included wave parameters, wind-induced currents, and water surface setup/setdown. Modeling the effects on a particular wreck required inclusion of shipwreck parameters such as length, beam, and orientation. With these data in hand, a wave analysis was performed to estimate the conditions at each wreck during the storm periods.

3.2 Methodology

3.2.1 Environmental Data

Environmental data for the hurricane periods were taken from a hindcast study of Hurricanes Katrina and Rita performed by Oceanweather, Inc. (2006). The final product of their study consisted of three model domains: a coarse grid of the entire GOM during both hurricanes, as well as a fine grid for each hurricane in the vicinity of their respective landfall locations. Since the studied wrecks are relatively close to the coast, data from the finely resolved grids was used in the wave study. Due to the small spatial range of the fine domains, a time series of storm conditions was available only for the closest hurricane to each shipwreck location. Table 5 outlines the relevant environmental parameters at each wreck location extracted from their respective hindcast node (all modeling parameters discussed in this section were calculated in metric units, but the English unit equivalents are provided for reference).

Table 5

Peak Hindcast Parameters for Each Shipwreck Location

Wreck	USS *Castine*	*New York*	*Gulf Tide*	Site 323
Grid (Hurricane)	Katrina	Rita	Rita	Rita
Node ID	7075	34444	40027	36320
Depth (m [ft])	36.5 (119.8)	19.1 (62.7)	17.2 (56.4)	23.2 (76.1)
Peak Sustained Wind Speed (m/s [mph])	32.9 (73.6)	30.9 (69.1)	35.5 (79.4)	38.3 (85.7)
Peak Sustained Wind Direction (degrees)	289	265	219	125
Maximum Significant Wave Height (m [ft])	9.8 (32.2)	5.5 (18.0)	6.9 (22.6)	9.4 (30.8)
Associated Period (swell, seconds)	16.2	11	12	14.4
Peak Period (swell, seconds)	16.4	15.5	15.5	16
Peak Swell Direction (degrees)	128	98	112	191
Surface Setup (m [ft])	1.23 (4.0)	0.45 (1.5)	0.94 (3.1)	1.19 (3.9)
Surface Current (m/s [mph])	1.31 (2.9)	0.87 (1.9)	1.53 (3.4)	1.81 (4.0)

Data from Oceanweather, Inc. (2006).

In Table 5, wind direction is in meteorological convention (from which the wind is traveling), clockwise from north (0 degrees [deg]), significant wave height represents the largest waves encountered in the entire hindcast time series for each wreck. The associated period is the wave period concurrent with the significant wave, while the peak period is the highest period in the hindcast time series for that node. Swell direction is in meteorological convention (from which the swell is traveling), clockwise from north (0 deg). Surface setup is the increase in sea level forward of a breaking wave front. The direction of the surface current is the same as the swell direction.

3.2.2 Shipwreck Data

Information concerning the shipwrecks was also necessary to perform the hydrodynamic analysis. These data were collected using several methods, including side-scan sonar surveys and physical inspection of the wrecks via diving, performed by PBS&J. Table 6 outlines the physical parameters of each shipwreck used for the analysis.

Table 6

Shipwreck Physical Parameters

Wreck	USS *Castine*	*New York*	*Gulf Tide*	Site 323
Length (m [ft])	65.2 (214)	48.8 (160)	30.5 (100)	61 (200)
Beam (m [ft])	9.8 (32)	6.7 (22)	6.1 (20)	10.1 (33)
Approx. Height (m [ft])	1.8 (6.0)	0 (0)	2.1 (7.0)	2 (6.5)
Orientation (deg)	316	170	69*	200

*Diving determined the orientation of *Gulf Tide*'s bow to be 249 deg after the wave interaction modeling had been completed. The error does not affect the results; however, Table 6 and Figures 12 and 14 reflect the erroneous bow orientation.

The length, beam, and approximate height measurements refer to the portion(s) of the hull that are exposed or above the seafloor. Orientation is the direction that the bow is facing, clockwise from north.

3.2.3 Wave Model

The shipwrecks in this study were situated in relatively shallow water with respect to the heights of the waves they encountered during Hurricanes Katrina and Rita. The use of either linear wave theory or Stokes 5th order theory will not provide accurate results for large waves in shallow water. Therefore, this study implemented a wave model that uses non-linear stream function wave theory, first developed by Dean (1965), so that the analysis was valid throughout the range of conditions at each site examined. This theory is fully nonlinear and is mathematically valid from deep water where waves are not affected by bathymetry, all the way to shallow water and near breaking wave conditions.

The calculation scheme used in this analysis was first developed by Chaplin (1999). It automatically determines the necessary order of nonlinearity for the wave calculations and includes wave interaction with a depth-uniform current. Results of this program compare favorably with that of Dalrymple's (1974) stream function formulation. Wave model calculations were computed in the MATLAB programming environment.

3.2.4 Model Input

The wave model can resolve a monochromatic wave train in two dimensions (vertically from crest to seafloor and horizontally along the direction of motion) plus time. The spatial domain can be extended to three dimensions by assuming a uniform wave perpendicular to the direction of travel.

The first step in the calculations is to enter the wave, current, and bathymetry parameters to determine a set of coefficients to define the resulting wave at each wreck location. Table 7 shows the parameters entered into the wave calculations for each wreck.

Table 7

Parameters Used for Wave Calculations

Wreck	USS *Castine*	*New York*	*Gulf Tide*	Site 323
Wave Height (m [ft])	9.8 (32.2)	5.5 (18.0)	6.9 (22.6)	9.4 (30.8)
Wave Period (seconds)	16.4	15.5	14	16
Water Depth (m [ft])	37.73 (123.79)	19.55 (64.14)	18.14 (59.51)	24.39 (80.02)
Uniform Current (m/s [mph])	0.5 (1.1)	0.5 (1.1)	0.5 (1.1)	0.5 (1.1)

The above wave heights are the significant wave heights from Table 5. The wave period is the peak swell period from Table 5, except in the case of *Gulf Tide*, where the period is the largest period that resulted in a stable wave solution in conjunction with the other parameters. The water depth is the depth plus the water surface setup at each hindcast node. The hindcast surface currents were reported at greater than 1 m/s (2.2 mph). Typically, the uniform current at the seafloor is a fraction of the surface value, but without any true data at the time of this analysis, 0.5 m/s (1.1 mph) was chosen as an appropriate approximation of the conditions expected at the project sites. This parameter should not be confused with wave particle velocity calculated at the seafloor by the wave model. The uniform current refers to the unidirectional background movement of water at the seafloor, upon which the much stronger bidirectional oscillation of wave particle velocity occurs. It is wave particle velocity that the authors refer to throughout the text as storm-induced bottom currents, and which is a major contributing cause of hurricane damage to shipwrecks. Uniform current is a necessary parameter of the wave model; however, it is not referred to outside of that context.

Once the wave coefficients were determined, a simplified two-dimensional ship model was used to approximate the wreck orientation relative to the incident waves. The model incorporated calculation points at the bow, center, and stern of the vessel. The wave coefficients and ship model were then combined to construct the three-dimensional (3D) plus time wave field over the wreck and extract time series of wave-induced velocities at the calculation points along the wreck.

3.3 Results

Table 8 contains a brief summary of the results of the wave modeling effort for each wreck. Figures 6 through 17 show the ship configuration, the wave profile, and the velocity time series for each of the four shipwrecks. The implications of these results are discussed in the following section.

Table 8

Summary of Wave Model Results

Wreck	USS *Castine*	*New York*	*Gulf Tide*	Site 323
Maximum velocity (m/s [mph])	2.6 [5.8]	2.5 [5.6]	2.9 [6.5]	3.4 [7.6]
Minimum velocity (m/s [mph])	–1.3 [–2.9]	–0.7 [–1.6]	–0.9 [–2.0]	–1.2 [–2.7]
Ship-wave orientation (approx. deg)	8°	72°	43°	9°
Bow-stern phase difference (seconds)	4	1	2	4

The ship configuration figures below (Figures 6, 9, 12, and 15) show how each wreck is aligned relative to the hindcast waves. The wave is traveling along the horizontal axis from left to right. The vertical axis is perpendicular to the wave propagation. Vessel orientation is reversed on Figure 12 because the wave model was performed before *Gulf Tide*'s bow and stern were identified. The orientation of the hull with respect to wave direction is important to understanding the intensity and direction of forces caused by wave-induced currents. The area of a ship's vertical profile determines its degree of exposure to currents, while the hull's orientation with respect to those currents affects the magnitude of their force upon exposed surfaces.

The wave profiles (Figures 7, 10, 13, and 16) show the wave surface as well as water particle velocity magnitudes and directions at an instant in time. The horizontal axis is the distance along the direction of wave propagation, with the origin being the center of the shipwreck. The vertical axis is depth relative to the still water level with positive values being upward. The solid black line in each figure is the wave crest profile. The hue represents water particle velocity magnitude, as shown in the scale on the right, with red meaning higher velocities. The vectors indicate the direction of water particle movement.

The velocity time series (Figures 8, 11, 14, and 17) show the timing of horizontal seafloor velocities at the different locations on each wreck indicated by circles of matching color on Figures 6, 9, 12, and 15. The horizontal axis is time, while the vertical axis is the horizontal velocity. Positive velocities are those in the same direction as wave propagation.

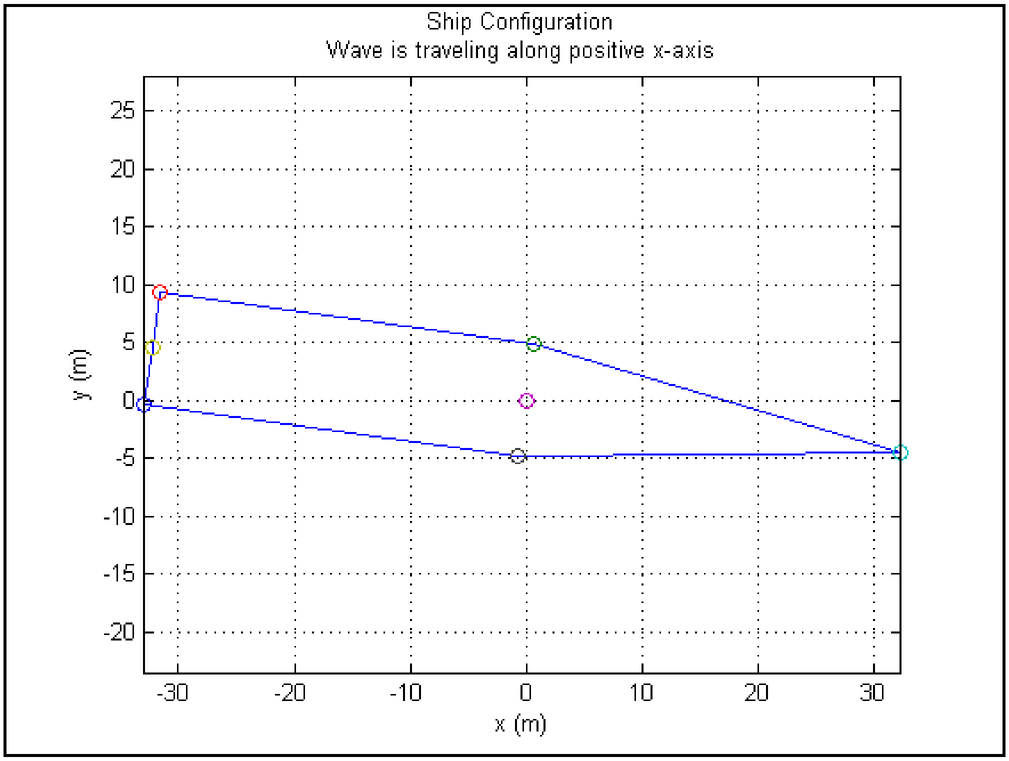


Figure 6. Ship alignment relative to incident wave, *USS Castine*.

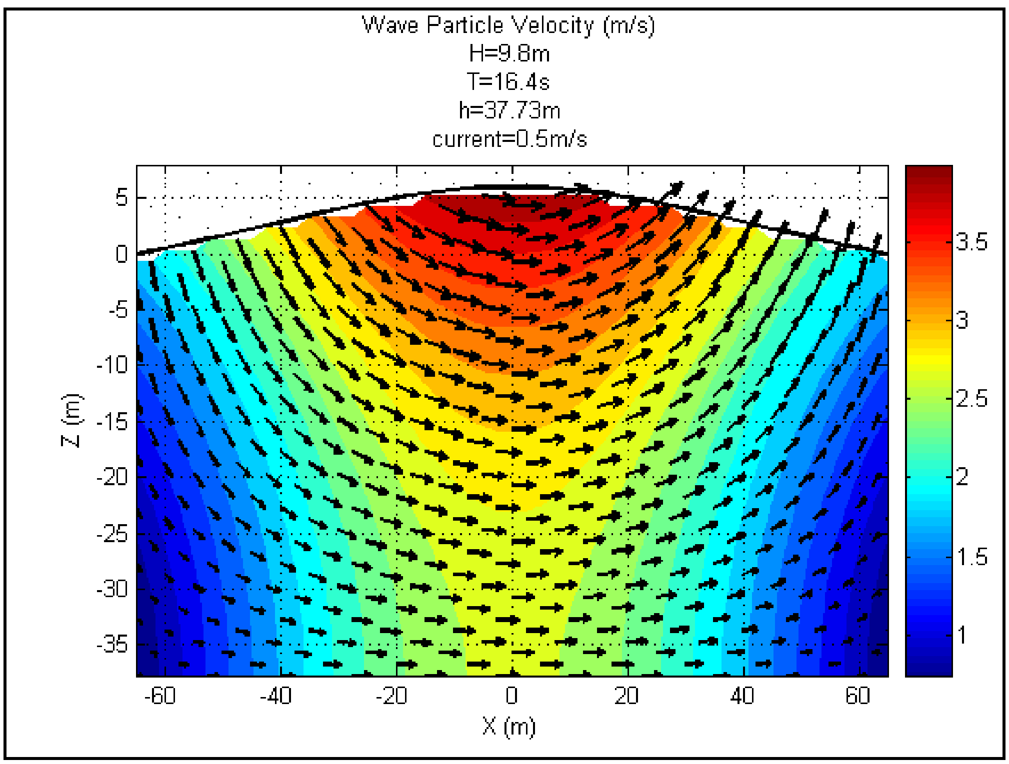


Figure 7. Wave profile, USS *Castine*.

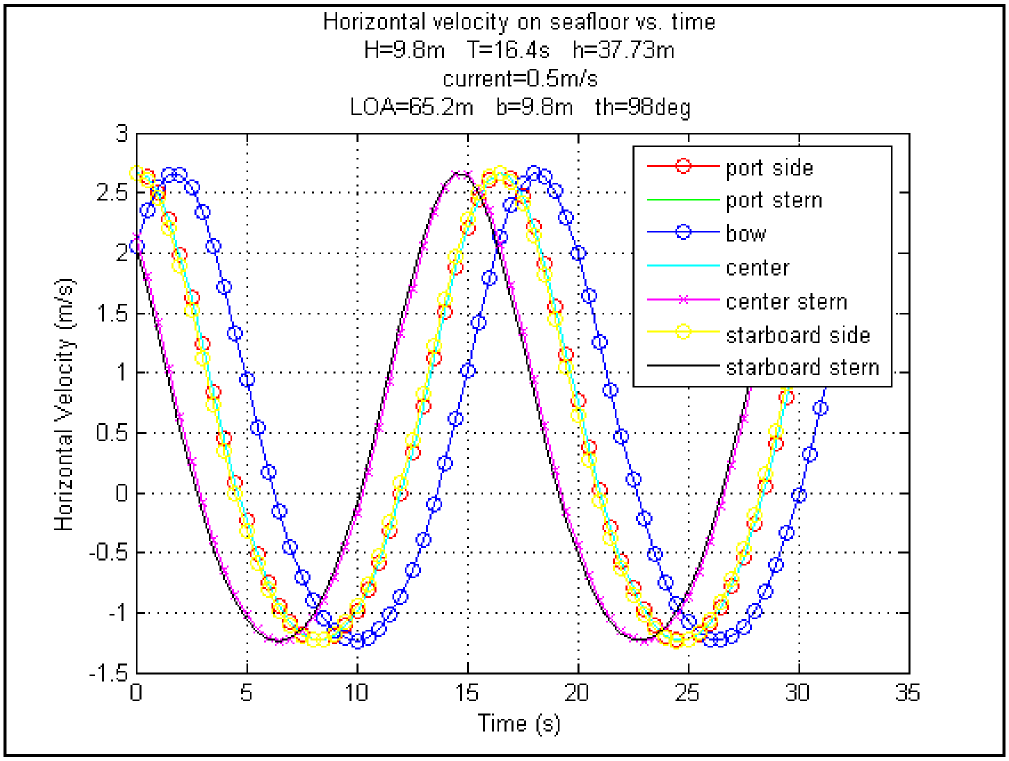


Figure 8. Velocity time series, USS *Castine*.

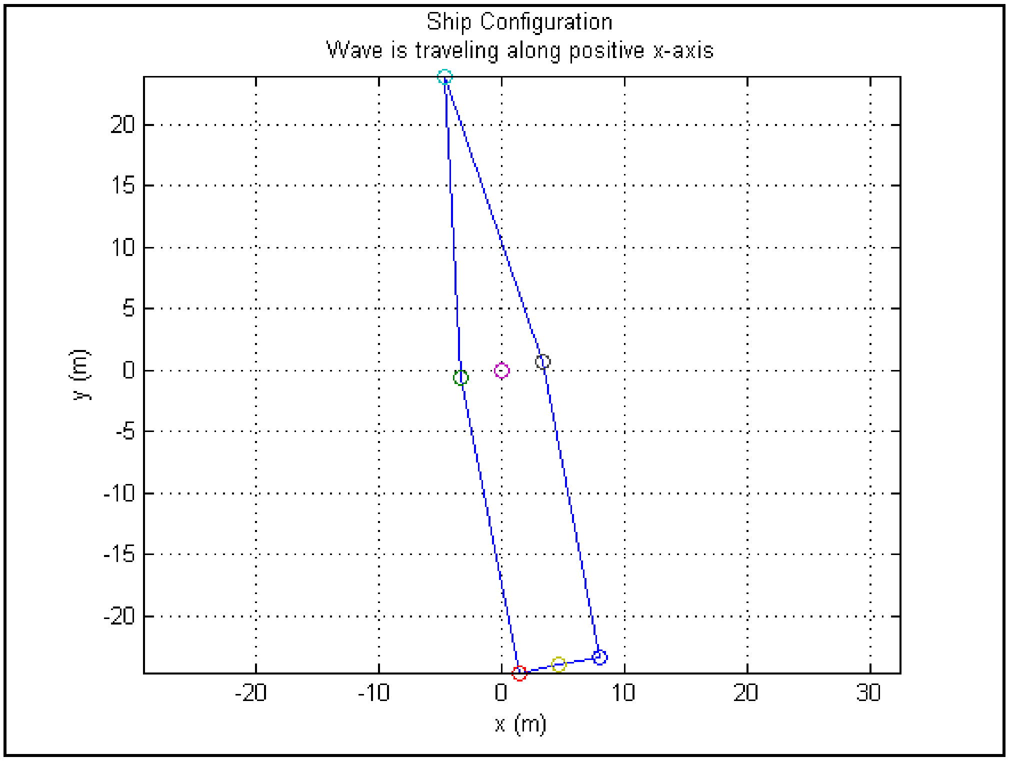


Figure 9. Ship alignment relative to incident wave, *New York*.

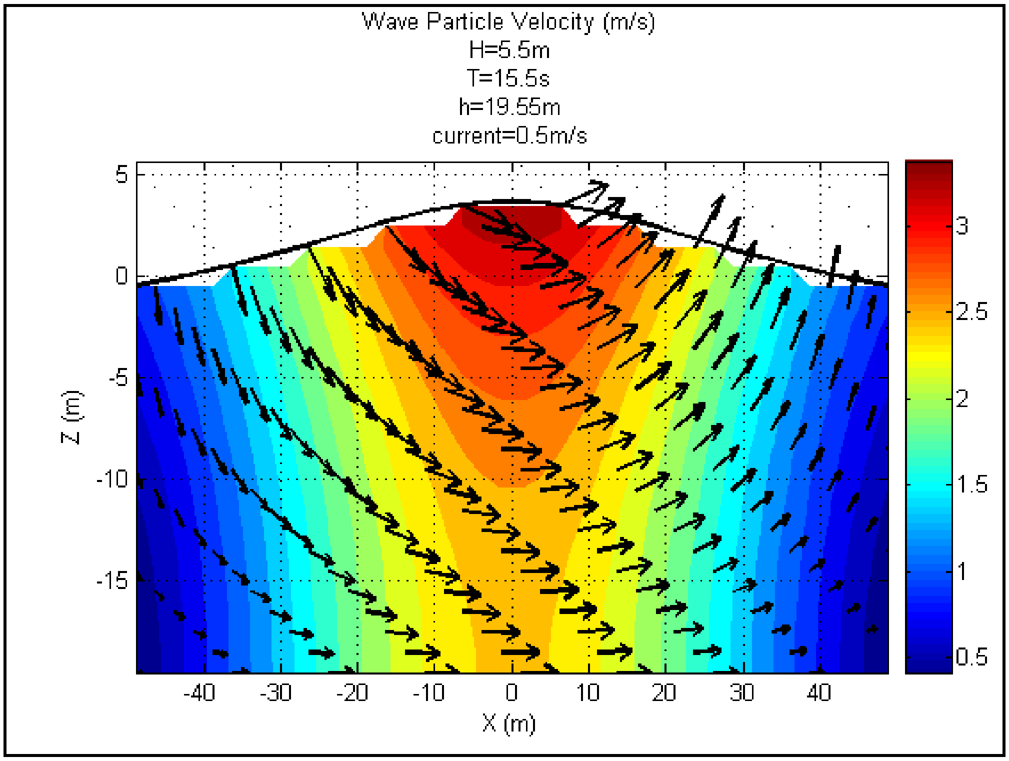


Figure 10. Wave profile, *New York*.

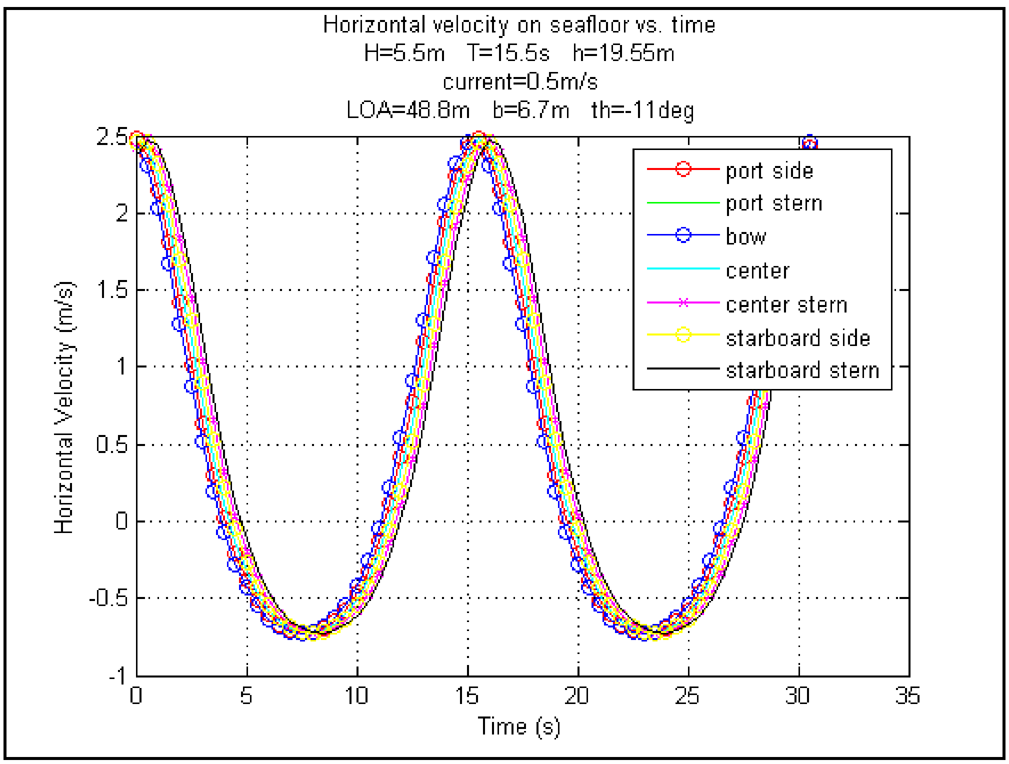


Figure 11. Velocity time series, *New York*.

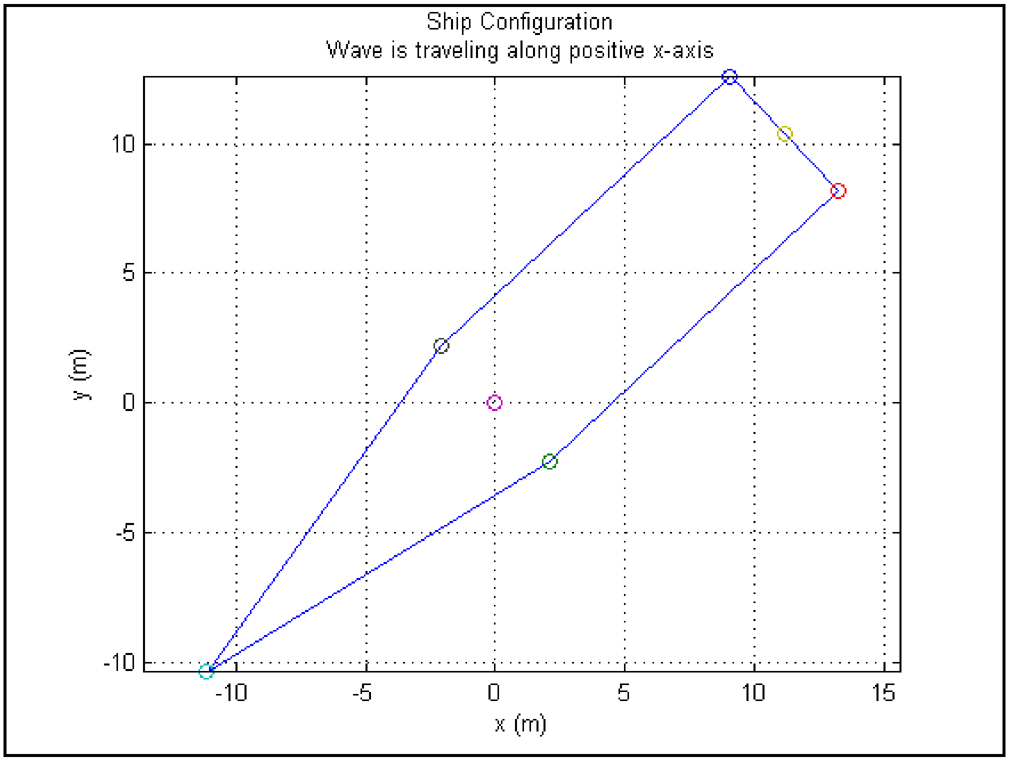


Figure 12. Ship alignment relative to incident wave, *Gulf Tide*.

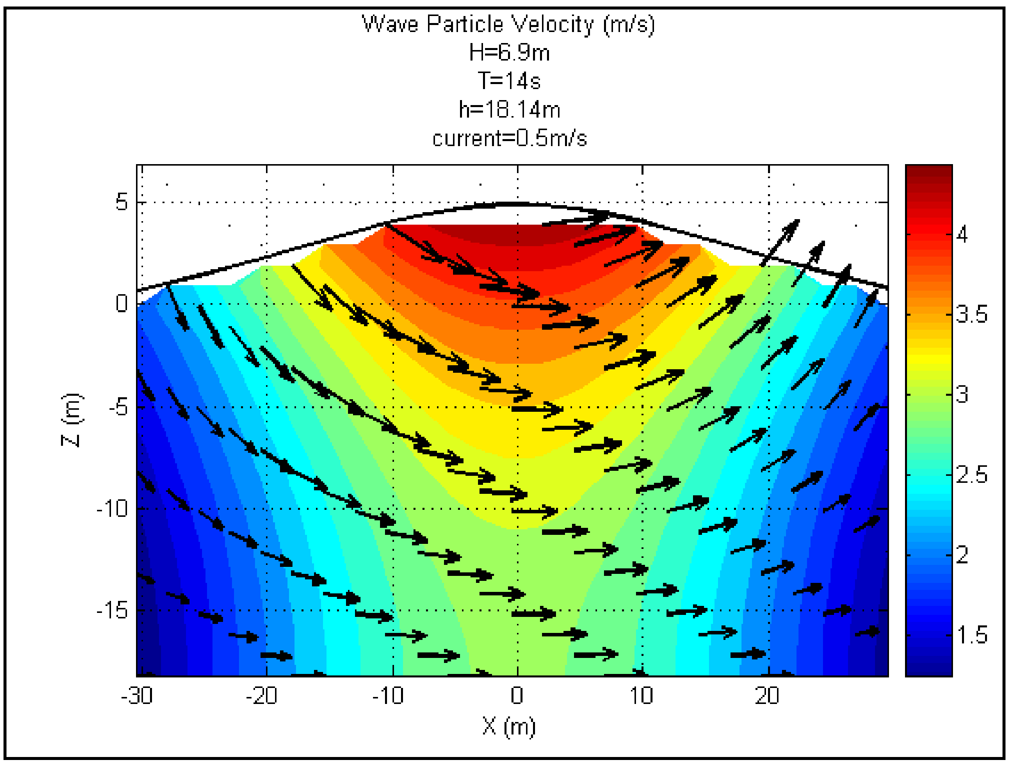


Figure 13. Wave profile, *Gulf Tide*.

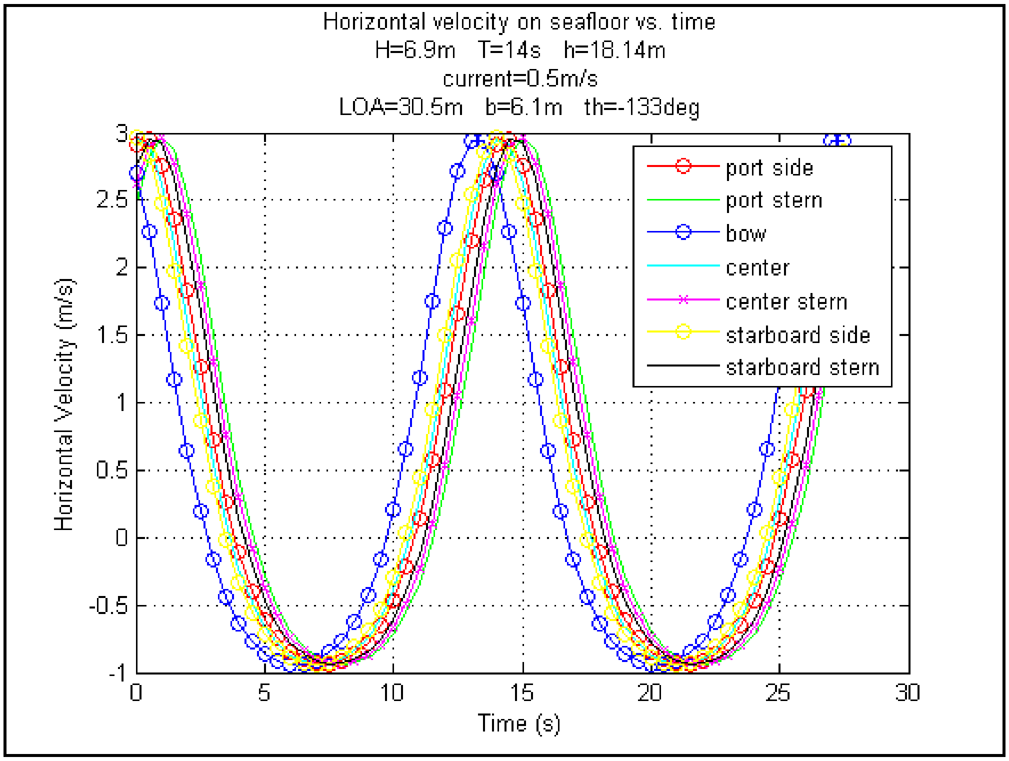


Figure 14. Velocity time series, *Gulf Tide*.

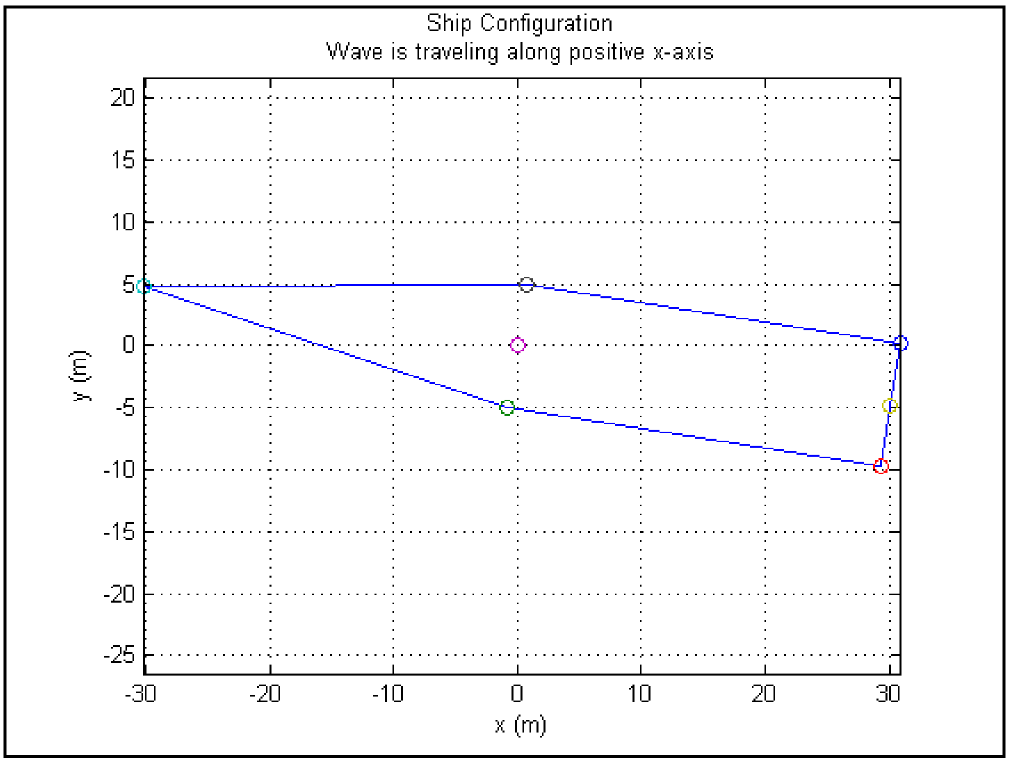


Figure 15. Ship alignment relative to incident wave, Site 323.

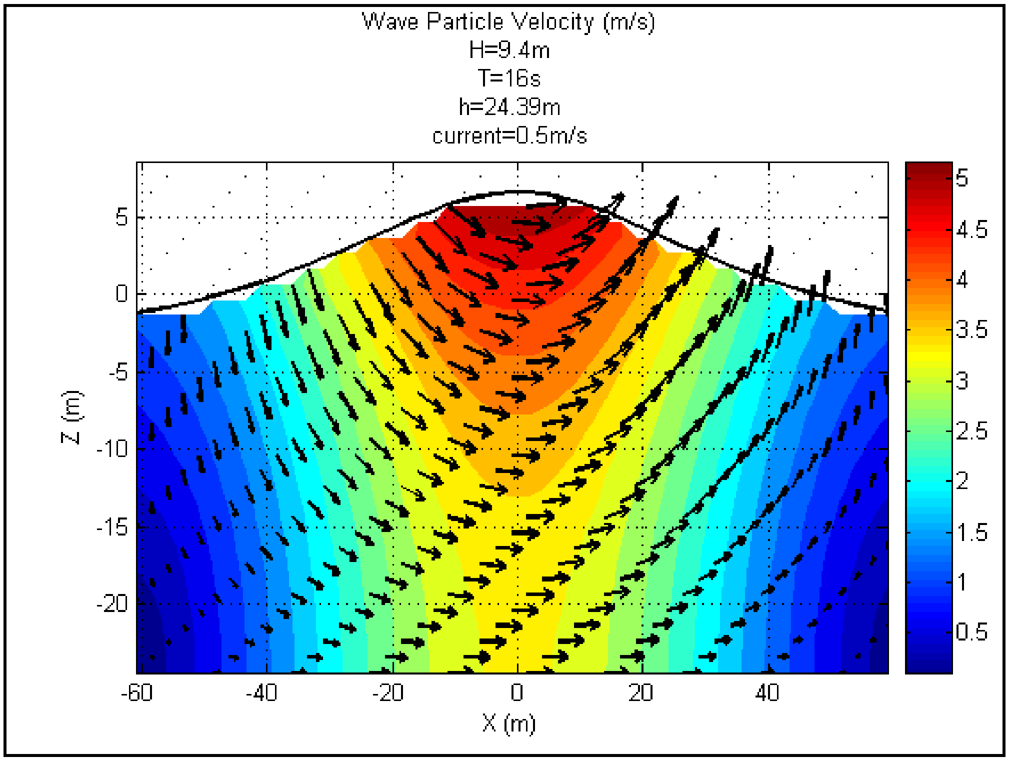


Figure 16. Wave profile, Site 323.

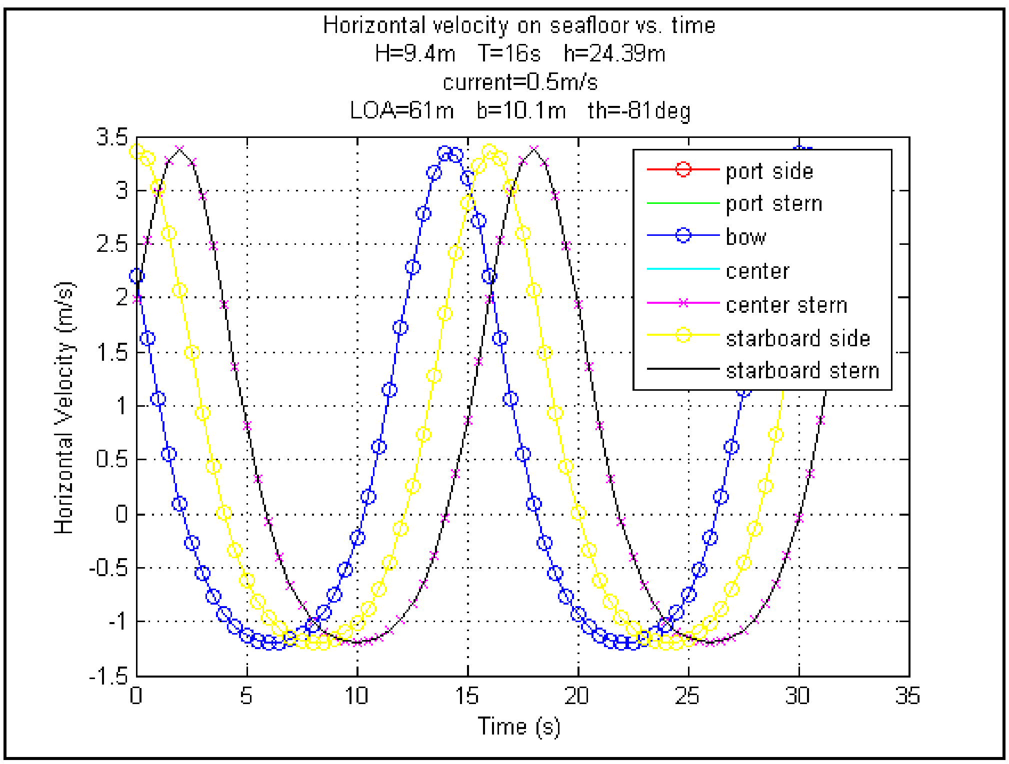


Figure 17. Velocity time series, Site 323.

3.4 Discussion

The results indicate strong bottom currents at each wreck site during peak storm conditions. Each site experienced a severe back and forth surge, as if in a giant washing machine. The current velocities ranged from 5.6 to 7.6 mph (2.5 to 3.4 m/s) in the direction of wave propagation (forward) followed by current velocities of –1.6 to –2.9 mph (–0.7 to –1.3 m/s) in the opposite direction only a few seconds later. The estimated period of this cycle ranged from 14.0 to 16.4 seconds (see Table 7).

The magnitude of force associated with water currents of such strength might be appreciated more easily by reference to wind speeds required to achieve the same effect. Most people have far more familiarity with judging significant wind speeds than water current velocities. Wind speeds capable of producing equivalent force were calculated based on the difference in density between seawater and air using the formula for drag force from fluid dynamics:

$$F_D = \rho v^2 C_D \frac{A}{2}$$

where

F_D is the force of drag, which by definition is the force component in the direction of the flow velocity,

ρ is the mass density of the fluid,

v is the velocity of the object relative to the fluid,

A is the reference area, and

C_D is the drag coefficient, a dimensionless constant.

The drag force on an object in air (F_{Da}) and water (F_{Dw}) are given, respectively, by:

$$F_{Da} = \rho_a v_a^2 C_D \frac{A}{2}$$

$$F_{Dw} = \rho_w v_w^2 C_D \frac{A}{2}$$

If these forces are to be equal, then:

$$\rho_a v_a^2 C_D \frac{A}{2} = \rho_w v_w^2 C_D \frac{A}{2}$$

Thus, the velocity of air (v_a) having a force equivalent to that caused by a given water velocity (v_w) is evaluated as:

$$v_a = v_w \sqrt{\frac{\rho_w}{\rho_a}}$$

Dry air has a density of 1.2754 kilograms per cubic meter (kg/m^3) (0.07962 lb/ft^3) at standard temperature and pressure (0 degrees Celsius [°C] and 100 kiloPascals [kPa] for the International Union of Pure and Applied Chemistry). Seawater has a density of 1,019.58 kg/m^3 (63.65 lb/ft^3) assuming for Hurricane Rita an estimated salinity of 30 parts per thousand and a seafloor water temperature of 25 °C (77 degrees Fahrenheit [°F]). Therefore:

$$v_a = v_W \sqrt{\frac{1{,}019.58 \frac{kg}{m^3}}{1.2754 \frac{kg}{m^3}}}$$

$$v_a = v_W (28.3)$$

Seawater velocity (v_w) must be multiplied by 28.3 in order to convert it to a wind speed (v_a) that would generate an equivalent drag force on an identical object in its path.

The results of the comparison between water current velocity and wind speed required to generate equivalent forces is shown in Table 9. The wind gusts required to generate equivalent forces on the four primary study wrecks would range from 158 to 215 mph (70.6 to 96.1 m/s) in the direction of wave propagation followed by winds of 44–82 mph (19.7 to 36.7 m/s) in the opposite direction only a few seconds later. In each case, the winds required to generate comparable forces are equivalent to a Category 5 storm on the Saffir-Simpson Scale, even though the actual storm winds above each site were no stronger than Category 1. Unlike the force of the storm winds raging above the waves, the force transferred by wave action to the seafloor becomes greatly magnified as the wave heights build and as the water depth decreases. The waves act in a sense like a battery accumulating energy from the wind, while the shoaling seafloor acts as a funnel to increase the water velocity. The effect of current force is compounded by the fact that the bottom currents completely reverse direction on the order of eight times per minute.

The repetitive reversal of force direction suggests that the underwater environment of the primary study wrecks during peak storm conditions was more analogous to a tornado than a hurricane. The Enhanced Fujita Scale, used by meteorologists to classify tornado intensity, describes an F3 tornado as having 3-second wind gusts of 136–165 mph (60.8–73.8 m/s) and causing critical damage. An F3 tornado is capable of overturning trains, uprooting most trees in a forest, twisting skyscrapers, and lifting heavy cars. An F4 tornado (winds of 166–200 mph [74.2–89.4 m/s]) causes devastating damage. Well-constructed houses are completely leveled and cars are thrown through the air. An F5 tornado (winds greater than 200 mph [89.4 m/s]) can throw automobiles in excess of 328 ft (100 m), badly damage steel-reinforced concrete structures, and cause significant structural deformation of high-rise buildings. The maximum currents experienced by the primary study sites are roughly equivalent to the force of an F3 (*Castine* and *New York*), F4 (*Gulf Tide*) or F5 (Site 323) tornado. It is little wonder that hurricane-induced currents are capable of inflicting substantial damage to sunken watercraft.

Table 9

Water and Wind Currents of Equivalent Force

	USS *Castine*	*New York*	*Gulf Tide*	Site 323
Maximum (forward) bottom current velocity (mph [m/s])	5.8 mph [2.6 m/s]	5.6 mph [2.5 m/s]	6.5 mph [2.9 m/s]	7.6 mph [3.4 m/s]
Forward wind speed required for *equivalent force (mph [m/s])	164 mph [73 m/s]	158 mph [71 m/s]	183 mph [82 m/s]	215 mph [96 m/s]
Minimum (reverse) bottom current velocity (mph [m/s])	–2.9 mph [–1.3 m/s]	–1.6 mph [–0.7 m/s]	–2.0 mph [–0.9 m/s]	–2.7 mph [–1.2 m/s]
Reverse wind speed required for *equivalent force (mph [m/s])	–82 mph [–37 m/s]	–44 mph [–20 m/s]	–57 mph [–26 m/s]	–76 mph [–34 m/s]
Combined amplitude of forward and reverse bottom current (mph [m/s])	8.7 mph [3.9 m/s]	7.2 mph [3.2 m/s]	8.5 mph [3.8 m/s]	10.3 mph [4.6 m/s]
Combined amplitude of *equivalent forward and reverse wind shear (mph [m/s])	247 mph [110 m/s]	202 mph [90 m/s]	240 mph [107 m/s]	291 mph [130 m/s]

*See text for description of concept and method used to calculate these values.

3.4.1 Hurricane-Induced Hydrodynamics in Shallow Water

The scope of this study required modeling the wave-current interaction at each of the primary study sites; however, the model also proved useful for examining the range of bottom currents occurring over a larger area. A broad aerial analysis was outside of the study scope; however, the authors felt it important that readers could visualize relationships between bottom currents and other variables, such as storm track, wind speed, wave height, and water depth as a storm moves into shallow water. A portion of Hurricane Rita's path was chosen for modeling (below). Rita, rather than Katrina, was chosen for this effort because three of the primary study wrecks occur nearest to Rita's path.

The following series of figures was based on hindcast data for 78 grid nodes from Oceanweather, Inc. (2006). The nodes were selected at 10-m (32.8-ft) water-depth intervals (from 10 to 60 m [33 to 197 ft] deep) at multiples of 10 nautical mi (11.5 mi [18.5 km]) from Rita's eye, measured at right angles to the storm track. The area of coverage extends 46 mi (74.1 km) west and 92 mi (148.2 km) east of the storm track. The asymmetrical coverage was selected in order to encompass wind fields of comparable intensity on either side of the storm. The locations of three of the primary study wrecks closest to Rita are plotted on each figure in the series. A maximum depth of 60 m (197 ft) was chosen because most artificial reef and pipeline damage occurs at depths less than 200 ft (61 m) (Table 3 and DNV 2007:57).

Figure 18 shows the maximum wind speed for the 78 grid nodes selected from Oceanweather, Inc.'s (2006) hindcast model. The maximum wind speed is centered slightly to the right of the storm's central path. Wind speed falls off more rapidly on the left side of the storm, while high winds extend much farther from the center on the right side. This pattern is typical of hurricanes, although the width of the wind field can vary significantly. Rita was a particularly large storm. Winds also decrease as portions of the storm come over land. In the case of Rita, the storm had already diminished substantially by the time its center reached the 60-m (196.9-ft) isobath, although Category 3 winds (>111 mph [50 m/s]) were sustained all the way to the 10-m (32.8-ft) isobath on the right side of the eye. The actual maximum wind speed was higher than shown in Figure 18, due to the fact that nodes selected for sampling were separated by 11.5 mi (18.5 km).

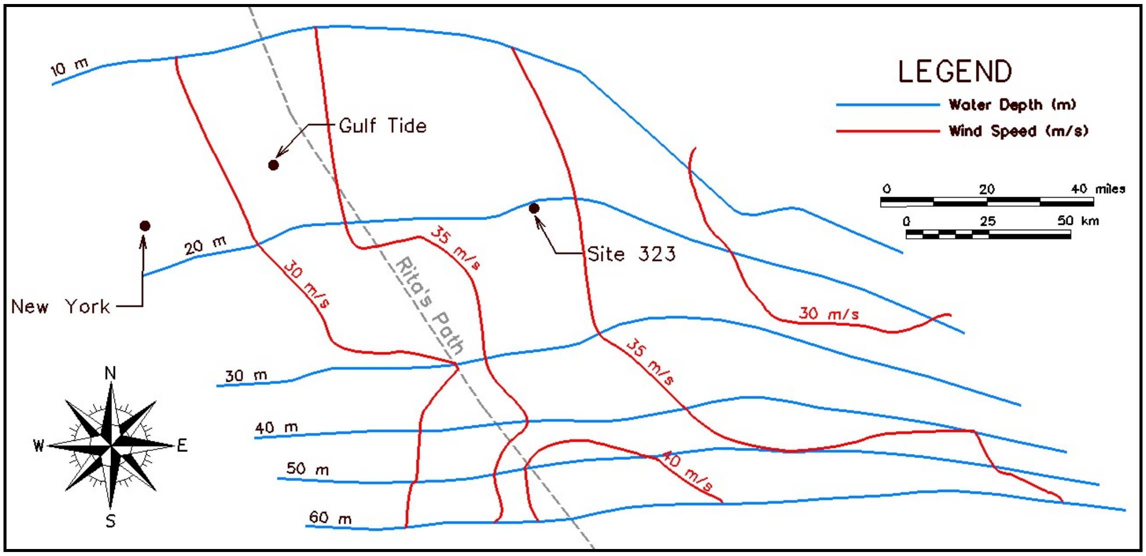


Figure 18. Maximum wind speed (m/s), Hurricane Rita.

Figure 19 shows the maximum significant wave height and wave direction from Oceanweather, Inc. (2006). Wave height diminished more rapidly on the left side of the storm. On the right side of the storm, wave heights of 7 m (23.0 ft) or greater carried shoreward to at least the 10-m (32.8-ft) isobath at a distance of 92 mi (148.2 km) from Rita's center. Wave height on the left side of the storm fell off to less than 3 m (9.8 ft) at the 10-m (32.8-ft) isobath only 46 mi (74.1 km) left of the eye. The direction of the largest waves is indicated by the vectors overlaid at each node position. This is the same direction as the maximum current forces generated at each node. In deep water, the largest waves tend to travel parallel to the storm path on its right side and travel away from the storm path on its left side. As the waves move into shallower water, their direction of travel deviates in a clockwise direction.

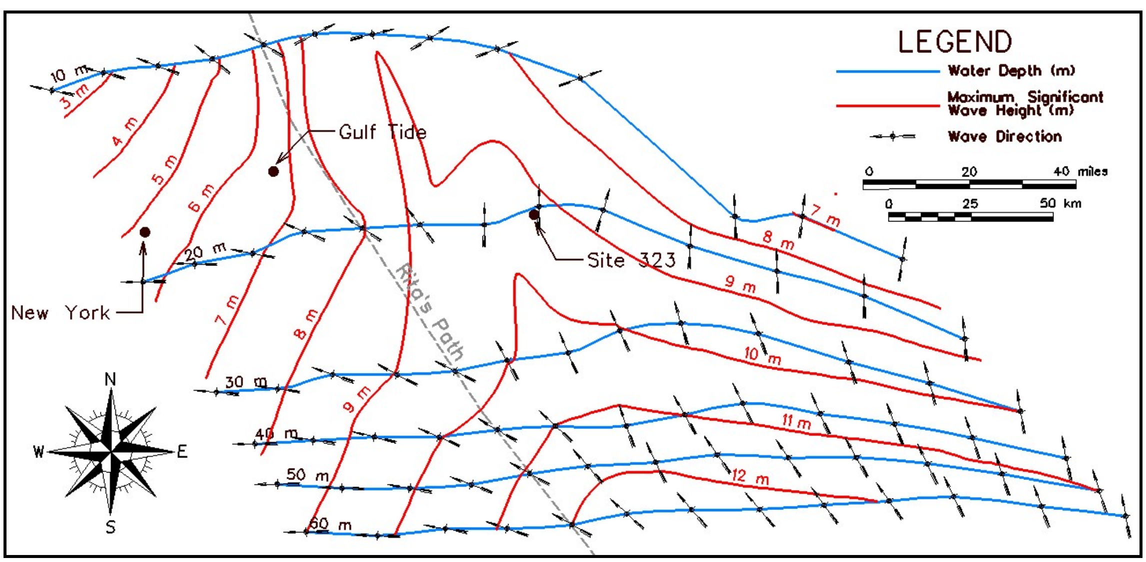


Figure 19. Maximum significant wave height and direction, Hurricane Rita.

The maximum velocity of bottom currents (Figure 20) induced by the storm waves increases on the right side of the storm path as water depth decreases, despite the fact that wave height steadily decreases at the same time. Figure 21 shows the same pattern for the total amplitude of the current change, which is the difference between the maximum (forward) and minimum (reverse) velocities. On the left side of Rita, the maximum current velocity and the change in current velocity (the difference between forward and reverse currents within a single wave cycle) remained fairly constant as water depth decreased, but both diminished with increasing distance from the storm path due to decreasing wave height.

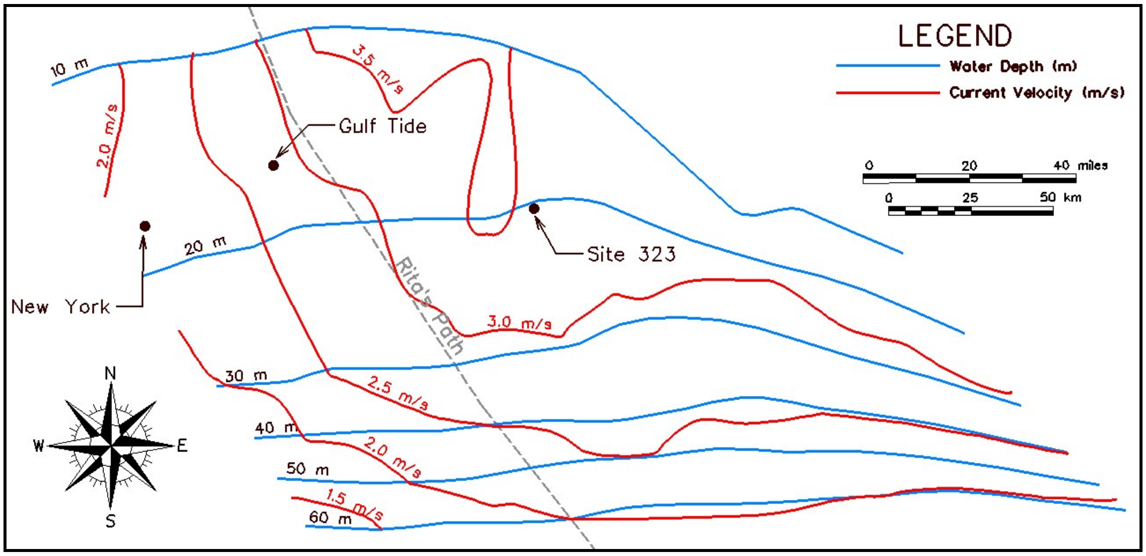


Figure 20. Maximum bottom current velocity (m/s), Hurricane Rita.

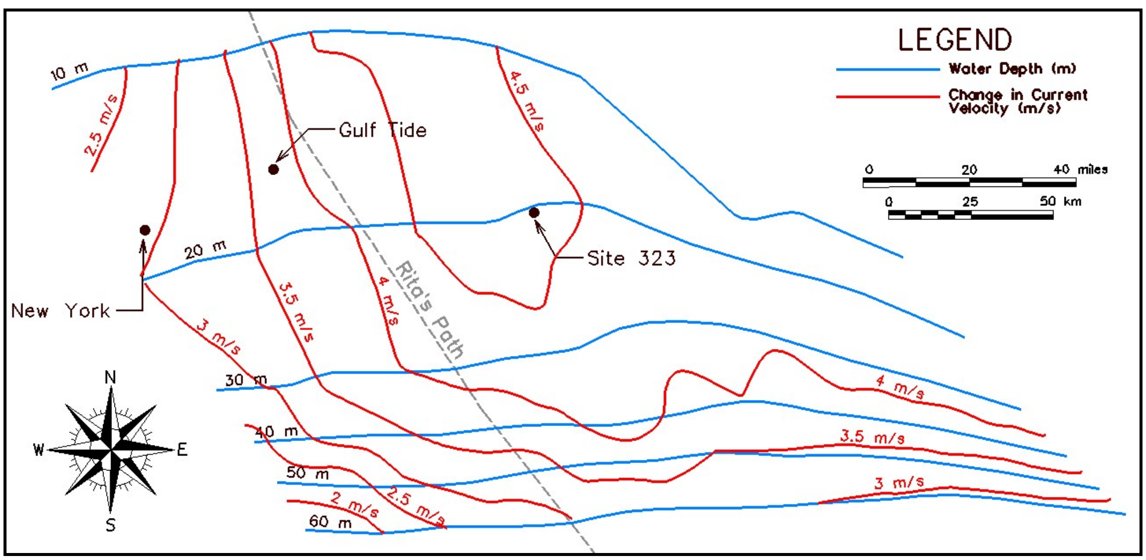


Figure 21. Maximum change in current velocity (m/s) in a single wave cycle, Hurricane Rita.

As each wave passes, there is a substantial change in pressure at the seafloor caused primarily by the change in weight of the water column from the trough to the top of the wave. The seafloor pressure (hydrostatic + dynamic) was calculated for the maximum significant wave heights at each of the 78 nodes used above. The results, calculated using Stokes 5th-order wave theory, are illustrated on Figure 22. The contours represent the pressure difference at the seafloor beneath the wave trough (minimum pressure) and crest (maximum pressure).

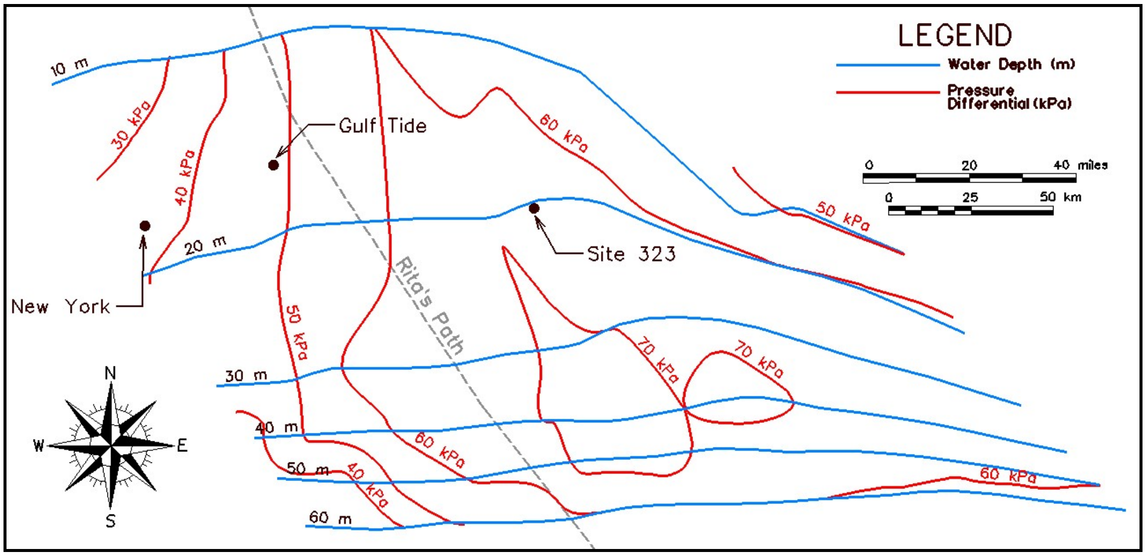


Figure 22. Maximum pressure differentials caused by passing waves (kPa), Hurricane Rita.

In the vicinity of Rita's path, the pressure on the seafloor due to intermittent waves on the Gulf surface varied by 50–70 kPa between wave troughs and crests. In comparison, a 3 m/s wave-induced current (approximately what was experienced on each of the four wrecks) causes a pressure of about 5 kPa on the seafloor, an order of magnitude less than the hydrostatic pressure differential; however, the change in hydrostatic pressure occurs more gradually than the change in current pressure. There are other complex factors that could cause damage to the wreck, including shear and twisting forces due to variations in forces along the wreck and hydrodynamic lift forces. Without more-sophisticated modeling techniques, it can be difficult to quantify the relative effects of one force versus another. Nonetheless, wave-induced currents causing forces comparable to major hurricane winds are without a doubt capable of inflicting extreme amounts of damage to seafloor objects.

The configuration of current velocity contours relative to Rita's path in Figures 20 and 21 should closely reflect the potential for shipwrecks to be damaged by hurricanes in waters less than 197 ft (60 m) deep. Stronger currents should result in greater potential for damage, all other factors being equal. Mapping the distribution of bottom currents associated with Hurricane Rita has been a useful exercise showing that the areas of greatest potential for damage do not correlate directly with either the strongest winds or the largest waves. This is due to the influence of water depth on the magnitude of storm-induced currents. Unfortunately there is no simple method for accurately predicting current magnitude or damage potential based on distance from a storm path or wind speed or wave height at a particular location. Damage potential is clearly related to current velocity, but current velocity itself is determined by a number of other factors including wave height, wave direction, and water depth. Wave height is determined by wind speed, fetch, width of the storm, the duration of strong winds (i.e., speed of the storm along its track), and water depth. Thus the strength of storm-induced bottom currents and the potential for damage at various positions relative to a storm's track will be influenced by the physical size and intensity of the storm, as well as by the shape of the seafloor and the orientation of the seafloor slope with respect to the storm track where the storm makes landfall. In general, however, the potential for damage should follow the distribution described above for storm-induced currents (see Figures 20 and 21).

The entire area mapped in Figures 18–22, extending 46 mi (74.1 km) west and 92 mi (148.2 km) east of Hurricane Rita's track, experienced maximum current velocities and shear forces at the seafloor roughly equivalent to or greater than that caused by the wind of an F1 tornado. Based on these results, the potential for shipwreck damage would appear to extend into waters deeper than 197 ft (60 m). The deepest artificial reef vessel reported damaged in Table 3 was at a depth of 210 ft (64 m); however, most reef vessels are sunk at shallow depths accessible to divers. Oceanweather, Inc. (2006:4) states that water less than about 246 ft (75 m) tends to become well-mixed by hurricanes from the surface to the seafloor, suggesting that wave energy reaches at least to that depth. Most pipeline damage has been reported at depths less than 200 ft (61 m), although small numbers were reported damaged by exposure or spanning during hurricanes Katrina and Rita at depths down to 300 ft (91 m) (DNV 2007:92). DNV go on to state that "these are the depths where historical pipeline damages not readily apparent from the surface have taken place as a result of hurricanes." The maximum depth of hurricane damage to shipwrecks remains uncertain; however, the authors believe that limit might be closer to 300 ft (91 m) than 200 ft (61 m).

4.0 RESULTS

This chapter provides a site-by-site presentation of the accumulated pre- and poststorm knowledge of each of the four primary wreck sites. A brief historical sketch (when known) is followed by the results of additional archival research; a description of previous investigations and prestorm conditions at each site; results of the May 2007 remote-sensing survey including a comparison with prestorm data; observations from the October 2007 diver investigations; results of the sediment coring; an analysis of poststorm observations and assessment of hurricane impacts; and, finally, an assessment of each site's eligibility for listing in the NRHP.

4.1 Methods

4.1.1 Remote-Sensing Survey

The remote-sensing survey cruise was conducted May 7–11, 2007, aboard the M/V *Fling*, a 100-ft (30.5-m) converted crew boat out of Freeport, Texas. Per the contract scope of work, the remote-sensing surveys were to include a marine magnetometer and side-scan sonar. Geophysical instrumentation employed in the field included a Geometrics G-882 magnetometer and an Edgetech DF1000 side-scan sonar. An additional Marine Magnetics Explorer magnetometer and Marine Sonics side-scan sonar were on-board as backups in case of failure of the primary survey instruments. Data acquisition utilized Coda Geosurvey software for side-scan sonar, and Trimble Hydropro™ software for navigation and magnetometer data. Survey boundaries extended at least 984 ft (300 m) beyond the center of each site, and transects were spaced at 98.4-ft (30-m) intervals. Towfish laybacks were adjusted to achieve instrument altitudes of not more than 20 ft (6.1 m) above the highest point on each site.

Following completion of the remote-sensing survey, the side-scan sonar data was processed to provide a complete "visual" record of the wreck sites and surrounding seabed. The CODA sonar acquisition software integrated UTM positions with the sonar graphic image, which was stored automatically to electronic media. A composite mosaic map was created from the original stream of data recorded in the field. The sonar mosaic was then converted to a geotiff format, with a resolution of 10 pixels per meter, and imported into Bentley Systems Inc. MicroStation© CAD software (version 8). This allowed viewing the mosaic in juxtaposition with other survey data such as magnetic contours and prestorm sonar imagery.

4.1.2 Diving Investigations

The diving cruise was conducted between October 1 and October 10, 2007, also aboard the M/V *Fling*. PBS&J's dive team consisted of six archaeologists and two scientific divers. Three members of the dive team, including the COTR, also participated in the cruise. All dives were conducted with standard SCUBA equipment, utilizing Nitrox breathing gas for extended bottom times. Additional equipment included a LinkQuest 1500 HA Ultra Short Baseline (USBL) diver positioning system. Dive rotations consisted of two-person teams with at least one diver wearing a USBL beacon and, when necessary, an AGA MKII full-face mask with surface communications.

Magnetometer and side-scan sonar data collected during the remote-sensing survey were supplemented during the diving investigations with collection of sector-scan and underwater acoustic camera imagery. A Mesotech MS1000 digital sector-scan sonar was used to collect stationary (as opposed to towed) imagery of all four sites from multiple angles. This imagery was often then used to direct diver operations to specific site features and to supplement formation of site maps. A diver-operated DIDSON™ acoustic underwater camera was also used intermittently on all four sites. This instrument provided the operating diver a visual reference to site features in low- or zero-visibility conditions. This "streaming" imagery was recorded in real time and later used to assist in identification and analysis of site features.

4.1.3 Box Core Collection and Analysis

Site conditions and storm model conclusions were supplemented where feasible by collection and analysis of box core sediment samples. The purpose of the sediment analysis was to characterize the substrate at each site, and to assess whether these results could be correlated with observed impacts to the wrecks. Specifically, sediment particle size and type (sand, silt, clay, gravel, etc.) were the variables analyzed.

The scope of work for this study stipulated the use of a box core device to collect sediment samples. A modified Klovan-style metal box core device, as employed by Beavers (1999; Figure 23) was custom-built for this study. After researching various designs of box coring devices, PBS&J selected the modified Klovan type because it was diver-controlled rather than needing to be deployed from a winch on the deck of the survey/dive vessel.

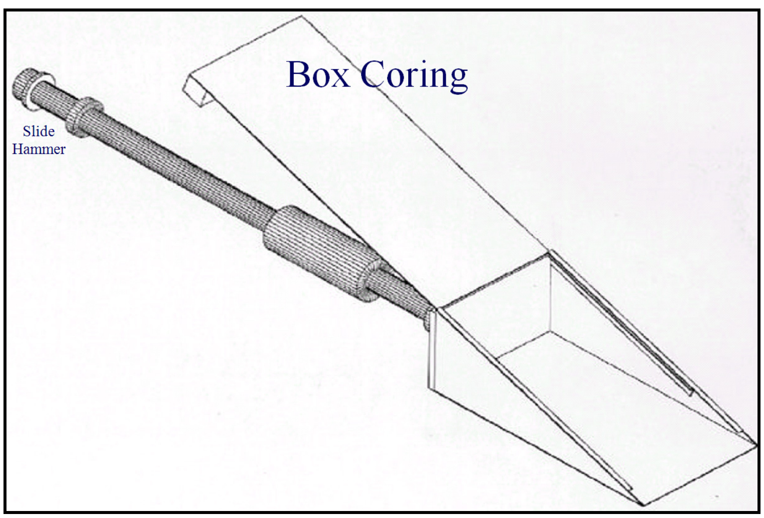


Figure 23. Diver-operated box core (Beavers 1999:95).

The stainless steel coring boxes measured 6 inches (15.2 cm) wide by 4 inches (10.2 cm) deep by 12 inches (30.5 cm) long. Each box had a panel that slid along furrows on either side of the open face of the box, effectively opening and closing the box core. Divers used a compass to orient coring units parallel and perpendicular to the ridge axis of bedforms. The coring units were hammered vertically into the sediment using a sliding weight. Once on the surface, each box core was allowed to dry out, and then a thin sediment profile was transferred to and sealed inside a rectangular Plexiglas box, preserving the stratigraphy for later lab analysis. This collection method was used only on the first two sites visited (Site 323 and *Gulf Tide*), because the device had to be jettisoned for diver-safety during the box core collection dive on *Castine* (the third site visited). Therefore, sediment collection methods at *Castine* and *New York* had to be improvised with available materials. At *Castine*, a sample was collected from the sediment adhered to the M/V *Fling*'s anchor, since wind, wave, and current conditions at that time prevented any further safe diving or core-collection on the site. For *New York*, cores were collected by hammering two 2-ft (0.6-m) lengths of 2-inch-diameter (5.1-cm) PVC pipe into the seabed and capping both ends. The sediment cores were extracted in PBS&J's lab. Though using multiple collection methods created inconsistencies in the sample volumes from each site, these inconsistencies had little to no effect on the overall data interpretation for three of the four sites. Stratigraphy of particle size and type, the primary data component, was preserved in both the box cores and PVC cores, and in each case there was a surplus of sediment beyond what was needed for lab analysis. The exception was *Castine,* in which, due to safety circumstances, only a non-provenienced surface sample from *Fling*'s anchor was able to be collected and analyzed.

The combined sediment samples were separated into a total of 16 subsamples: 8 from *Gulf Tide*, 4 from Site 323, 3 from *New York*, and 1 from *Castine*. Each of these subsamples was subjected to particle-size analysis in PBS&J's lab. Particle-size analysis is used to infer the mode and energy of sediment transport. The samples were measured for textural percentages using the hydrometer method, in accordance with Stoke's Law. This law states that individual grain sizes settle at a consistent rate given a particular height of water. Approximately 30 grams of each box core sample was deflocculated with sodium hexametaphosphate and then added to a 1,000-milliliter (ml) graduated cylinder. The cylinder was then filled with distilled water and agitated. Silt and clays were measured for a 24-hour period using a 152H, –5 to +60 grams per liter (g/L) hydrometer. Samples were then wet sieved to collect the heavy fraction. The sand was dried and then sieved in nested sieves. The individual phi size amounts were weighed and figured for cumulative weight percent to correspond with the data from the hydrometer. Particle-size classifications (see Tables 10, 12, 13, and 15) are based on the Krumbein phi logarithm to the Udden-Wentworth scale.

In addition to the particle size and type analysis of the box cores, PBS&J examined previously published maps of Pleistocene and Holocene soil distributions, and sediment shear strengths throughout the GOM (Dunlap et al. 2004; McClelland Engineers 1979). Pleistocene surfaces indicate consolidated sediments that were subaerially exposed during the last glaciation period from 24,000 to 6,000 years B.P., while Holocene sediments are the geologically recent and generally unconsolidated marine deposits that have accumulated over Pleistocene surfaces near modern and ancestral river systems (Keith and Evans 2009). Shear strength is known to correlate with content ratios of cohesive (i.e., clays and silts) vs. cohesionless (sand, gravel, cobble) sediments, which in turn contributes to the probability of shipwreck subsidence (Keith and Evans 2009). Higher shear strengths generally indicate predominantly cohesive sediments, decreased wreck subsidence, and increased wreck exposure above the seafloor. Shear strengths at wreck sites were not measured as part of this study, but considering the relationship of shear strengths to sediment classification, the McClelland Engineers (1979) and Dunlap et al. (2004) maps provided a frame of reference for the box core analysis. Unfortunately, the data nodes used to create these maps were widely spaced, and so provide only a general, interpolated characterization of the sediments surrounding each of the wreck sites. They are the closest data sets available, however, and for that reason were included for reference in the following discussion of results.

4.1.4 Archival Research

The majority of archival research was conducted over two weeks in January and February 2008. Repositories visited included the Mariners' Museum in Newport News, Virginia, the Library of Congress, and the National Archives branches in Washington, D.C., and College Park, Maryland. Additional research was conducted through phone and email correspondence with The Smithsonian Museum of American History, the Naval Historical Center, the U.S. Coast Guard Historian's Office, Lloyd's of London, and the Special Collections of the New York Public Library. Several newspaper archives were also searched for any published accounts of the various vessels' wrecking events.

4.1.5 NRHP Assessment

Assessment of each wreck's NRHP eligibility was based on U.S. Department of Interior guidelines for nominating historic sites to the NRHP (U.S. Dept. of the Interior, National Park Service [USDOI, NPS] 1985, 1997). Determination of a wreck's eligibility status is based on consideration of the three key concepts of **significance**, **integrity**, and **context**. In order for a site to be considered **significant**, it must be at least 50 years old and meet one or more of the following criteria:

A. *Be associated with events that have made a significant contribution to the broad patterns of our history; or*

B. *Be associated with the lives of persons significant in our past; or*

C. *Embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic value, or that represent a significant and distinguishable entity whose components may lack individual distinction; or*

D. *Have yielded, or may be likely to yield, information important in prehistory or history.*

Integrity is defined as "the authenticity of a property's historic identity, evidenced by the survival of physical characteristics that existed during the property's prehistoric or historic period" (USDOI, NPS 1997:4). A shipwreck maintains its integrity when it retains physical materials, design features, or construction details that can reveal important information about the period or persons that provide the basis for the wreck's significance. Integrity can be manifested in a shipwreck's hull construction, artifact assemblage, marine engineering, or other technological aspects.

Context is defined as "information about historic trends and properties grouped by an important theme in the prehistory or history of a community, State, or the nation during a particular period of time" (USDOI, NPS 1997:4). In other words, historic context provides the link between the shipwreck and unique, representative, and/or pivotal trends.

Presented below are the cumulative results of the multifaceted archaeological investigations for the wrecks of *Castine,* Site 323, *Gulf Tide*, and *New York.* Remote-sensing survey results for the remaining six secondary wrecks not selected for diver investigation are presented in Appendix A. Appendix A also includes a brief analysis of possible hurricane impacts to the sidewheel steamer

Josephine, based on sector-scan sonar imagery collected at that site in August 2007. Additional archival research on GOM wrecks not included in this study is presented in Appendix B.

4.2 *Castine*

The former USS *Castine* (BOEMRE site ID 15170; Figure 24) is located in the Grand Isle lease block area, 30.4 mi (48.9 km) west of Hurricane Katrina's path. It is the closest of any of the selected study sites to that storm. The site was initially recorded, though not identified, in 2001 by Thales Geosolutions (Floyd 2001). PBS&J identified and further recorded the site in 2005 as part of a study to conduct NRHP evaluations of submerged archaeological sites on the GOM OCS (Enright et al. 2006).

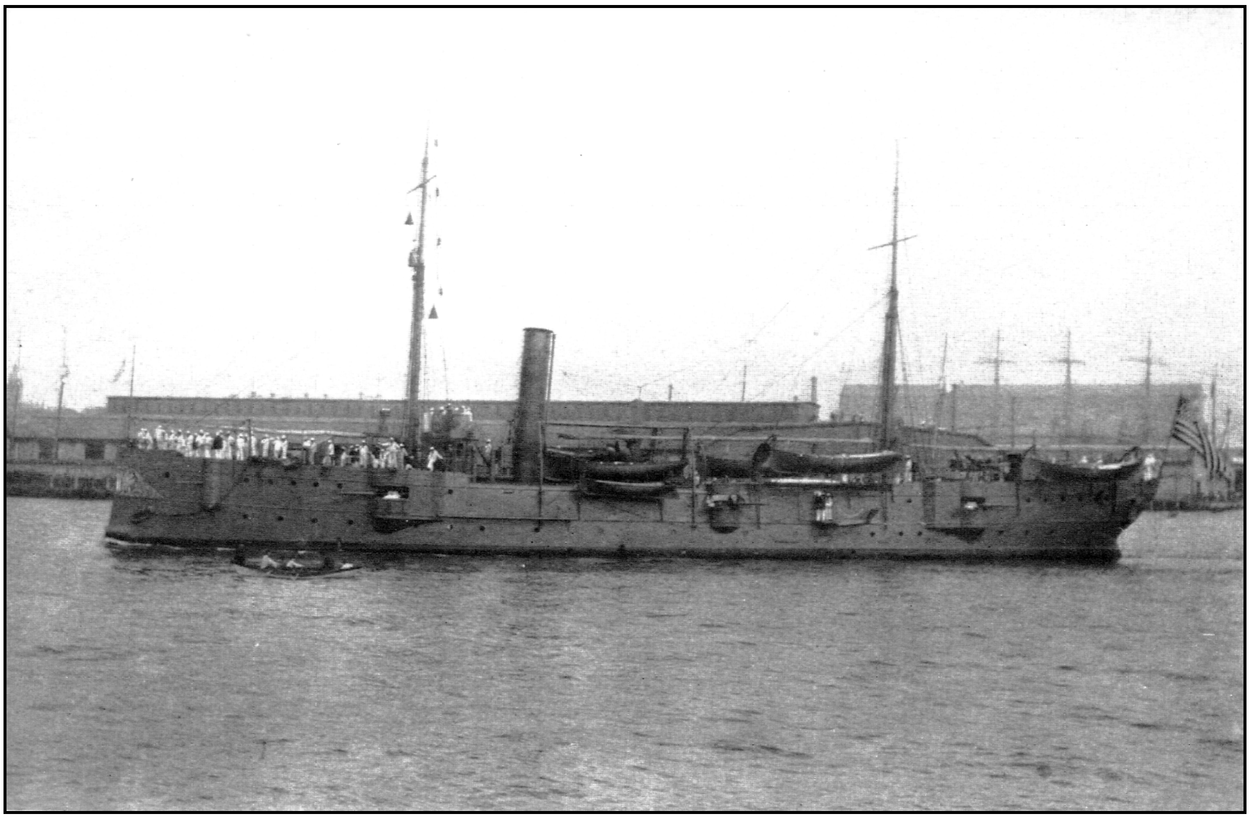


Figure 24. USS *Castine* at anchor, 1916 (Naval History and Heritage Command 2010).

4.2.1 History

Castine, also known as Gunboat No. 6, was built in 1892 at Bath Iron Works in Bath, Maine, along with her sister ship, *Machias* (Gunboat No. 5). Both vessels were named after Maine towns, and they are the first steel-hulled vessels built in Maine, as well as the first ships built by Bath Iron Works, one of the most prolific naval ship builders of the last century. During World War II, Bath Iron Works built one-quarter of the U.S. Navy's destroyer fleet and more destroyers than the entire Japanese Navy built during the same time (Toppan 2002).

Castine and *Machias* were early entrants in the so-called New Navy that replaced the rotting and neglected U.S. fleet after the Civil War. The New Navy essentially began with the Navy Act of 1883, which authorized the construction of several new steel cruisers and marked the navy's conversion from a primarily defensive fleet of obsolete wooden and ironclad warships, to a stronger, faster, steel-hulled fighting force capable of initiating offensive operations around the globe (Alden 1972:13). Within this ambitious shipbuilding program, gunboats were among the smallest rated warships, though paradoxically used as the workhorses of the fleet (Jones 2007). Lacking the speed, armor, and firepower of larger ships rated as 'cruisers,' they were not intended for ship-to-ship naval combat, but for blockading, scouting, troop support, and, in times of relative peace, projecting American naval power on "showing the flag" missions abroad. They were designed to operate independently for extended periods in foreign stations, were relatively inexpensive to build and operate, and were powerful enough to suppress native uprisings in third world countries where American interests were at risk. They were generally designed to be sturdy vessels with good endurance and relatively light draft. Many, like *Castine*, retained sails to supplement their light coal supplies and enhance operating range (Alden 1972).

The keel for the 1,177-ton *Castine* was laid on February 4, 1891, and the completed vessel was launched on May 11, 1892. Initially, *Castine* measured 190 ft (57.9 m) long with a 32-ft (9.8-m) beam and 12-ft (3.7-m) draft, though a top-heavy design necessitated cutting the vessel in half and adding an additional 14 ft (4.3 m) to the midsection shortly after its sea trials (*New York Times* 1894). The gunboat was schooner rigged with fore- and mainmasts (Barton and Denig 1893:847), and built with poop and forecastle decks atop a full-length gun deck (Figure 25). The main battery consisted of eight 4-inch (10.2-cm) rapid-fire rifles. Six of these were mounted in armored sponsons projecting from each side of the gun deck, and the remaining two were pivot-mounted on the topgallant forecastle and poop deck. The secondary battery was comprised of four 6 pounders: two in sponsons under the topgallant forecastle and two on the poop deck over the aft sponsons. There were also two 1 pounders firing directly aft from the after cabin, a Colt 0.30-caliber automatic amidships, and a Howell torpedo tube fitted through the stem and discharging above the waterline (Barton and Denig 1893:847; Bureau of Construction and Repair n.d.a). Both *Castine* and *Machias* were powered by twin vertical, inverted, direct-acting, triple expansion engines, producing a combined 2,200 horsepower, and capable of sustaining 16 knots (18.4 mph).

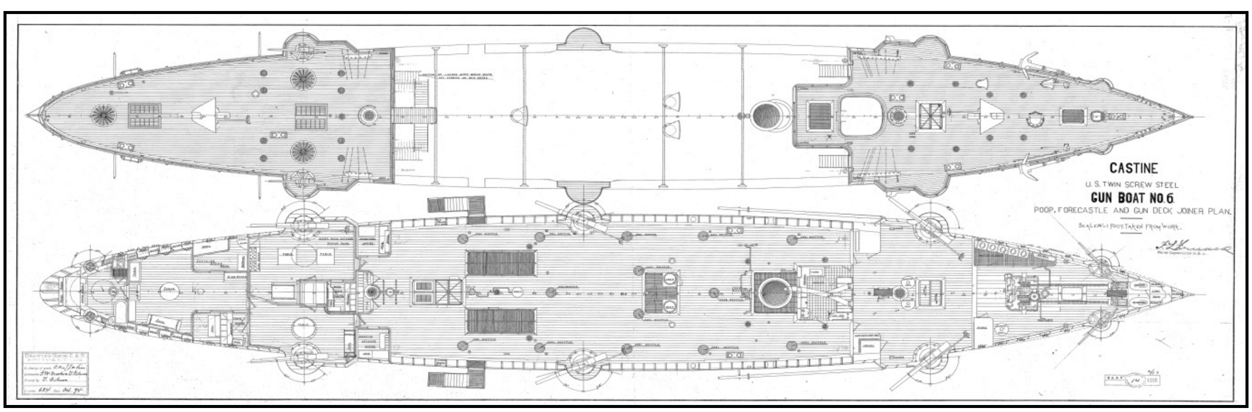


Figure 25. USS *Castine* deck plan (U.S. Bureau of Ships 1894).

Castine was commissioned on October 22, 1894, under the command of Commander Thomas Perry and joined the Atlantic Fleet with a complement of 130 crew, 12 marines, and 11 officers. The small gunboat was sent first to the east coast of Africa to protect a pair of American consuls who had become embroiled with local legal problems (*New York Times* 1895). After these issues were resolved, *Castine* stayed on station off east Africa for the majority of 1895 before getting recalled to the South Atlantic Station for cruising missions off of Brazil, Panama, and the West Indies.

The first wartime operations for *Castine* came a few years later during the Spanish-American War. The U.S. declared war against Spain on April 25, 1898, fighting, in part, for Cuban independence from their Iberian oppressors. *Castine* joined Admiral Winfield Scott Schley's Flying Squadron and, for the majority of the short-lived conflict was assigned to blockade operations off of Havana, Cienfuegos, Mariel, Matanzas, Cardenas, and Cabanas (U.S. Dept. of the Navy 1898). *Castine* was credited with at least three prize captures, and also provided convoy escort and artillery support for the 20,000 troop Army invasion that left Key West and landed at Daiquiri in June (*New York Times* 1898, 1900; *Newark Daily Advocate* 1898).

After the Treaty of Paris ended the Spanish-American War in December 1898 (actual hostilities had ceased in July), collateral violence erupted in the Philippines, which had been awarded to the U.S. in the treaty. Filipino insurgents, who had believed they were fighting alongside American soldiers for their own independence, quickly became disillusioned at the thought of trading Spanish masters for American ones and took up arms once more. The bloody, 3-year Philippine Insurrection had begun, and *Castine* was once again sent to hostile shores.

The Navy's role in the conflict was primarily to support army operations. This typically took the form of blockades, artillery support for troop landings, and transport of troops and supplies (Williams 1985:101). Gunboats were overwhelmingly the vessel of choice for these naval operations. They had both the firepower to repel land-based insurgents and the ability to navigate the innumerable shallow waterways that dissected the 8,000 Philippine Islands. *Castine*'s most notable service during the Insurrection came when its captain, Commander Samuel Very, orchestrated the surrender of Zamboanga, the largest city on Mindanao, itself the second largest island in the archipelago and a major insurgent stronghold (*New York Times* 1899).

Shortly after the fall of Zamboanga, *Castine* was dispatched to China to join an international force in the process of subduing the Boxer Rebellion. The Boxers were a radical religious sect that had violently revolted against Chinese Christians and the encroachment of non-Chinese imperial governments. The violence was focused against international legations in Peking (now Beijing), but *Castine* was stationed in Shanghai between March and August 1900 to protect American interests against a threatened uprising that never materialized (Leahy 1897–1931). The Boxer Rebellion was effectively defeated in August 1900, and *Castine* was sent back to support army operations in the Philippines until June 1901, when it was finally ordered back to the U.S. and decommissioned (the Insurrection officially ended in 1902).

Following its service in the Pacific, *Castine* entered an extended period of peacetime cruises, punctuated by periods of decommissioning and repair. *Castine* was placed back into commission in 1903 and returned to service in the South Atlantic Squadron. Through 1905, the gunboat cruised the Mediterranean, west coast of Africa, east coast of South America, the West Indies, and the Dominican Republic (Anonymous 1925). Following another decommissioning from 1905 to 1908, *Castine* was assigned to the newly created Atlantic Submarine Flotilla. In this unit, *Castine* served as the principal submarine tender and also, from 1912 to 1913, as the flagship for the flotilla's commanding officer, Lieutenant Chester Nimitz. As an Admiral, Nimitz would later become a legendary naval officer during World War II.

Castine returned to duty as a gunboat in 1914, and for the next three years was primarily engaged in mediating violent revolutions that had erupted in the Dominican Republic and Haiti. From May 1914 to March 1917, *Castine* spent the majority of its time cruising between Santo Domingo, Dominican Republic, and Port-au-Prince, Haiti, monitoring the conflicts and protecting American interests (Commander, Cruiser Force 1916; Commander, Cruiser Squadron 1916a, 1916b). During this time, *Castine* was also involved in one of the worst peacetime tragedies in U.S. naval history. On August 29, 1916, *Castine* and the cruiser *Memphis* were at anchor off Santo Domingo when a massive tsunami swept into the harbor. *Castine* was able to fire its boilers in time and escape, despite suffering flooding in its engine room, cabin, and magazine, and the deaths of a couple crewmen who drowned after one of the ship's boats capsized. *Memphis* was far less fortunate. The cruiser could not gather steam in time and was caught broadside to the wave, which drove the ship against the rocks, a total loss. Over 40 of *Memphis*'s crew died in the disaster, either from drowning, burns, or steam inhalation (U.S. Naval Historical Center 2005).

Following repairs to the battered gunboat, *Castine* was dispatched to the Mexican Patrol to once again protect American interests during the Mexican Revolution. *Castine* remained on patrol in Mexico from March 3 to July 4, 1917, at which time it was called back to the U.S. and ordered to "fit out for distant service," joining the Allied response to German U-boat dominance in the Atlantic during World War I (Anonymous 1925).

The war had begun in 1914, and Germany declared unrestricted U-boat warfare in February 1917. The U.S. entered the war in April of that year and responded in part by sending light, fast, highly seaworthy vessels to Atlantic war zones for patrol and convoy escorts (Knox 2003). *Castine*, along with its sister ship *Machias,* was sent to Gibraltar, the gateway for more shipping traffic than any other part of the world at the time, and the key to communication lines for allied armies in Italy, Greece, North Africa, and the Middle East. Gibraltar comprised the largest contingent of U.S. anti-submarine forces, and *Castine* spent most of its time during the war on patrol and convoy escort between Gibraltar and a transfer point at Oran, Algeria (Knox 2003; USS *Castine* 1917).

These combined operations were instrumental in nullifying Germany's U-boat dominance, so much so that merchant shipping losses decreased from a peak of 900,000 tons in April 1917 to only 28,000 tons by October 1918 (Halpern 1994). Germany ended its U-boat offensive that same month, and *Castine* stayed on patrol at Gibraltar for two more months before leaving with its final convoy to the Azores on Christmas Day.

Castine arrived at New Orleans in January 1919 and underwent its final decommissioning on August 28. The gunboat was put up for auction the following year, and on August 5, 1921, was sold to A. Marx & Sons of New Orleans for $12,500 (Bureau of Construction and Repair n.d.b). The vessel was again sold in July 1923, to the Maritime Trading Corporation for $40,000 (U.S. Dept. of Commerce, Bureau of Navigation n.d.), and conflicting records show it being owned the following month by the Equitable Equipment Company and the New Orleans Menhaden Company. It is clear, however, that the latter company owned the vessel in December 1924, when *Castine* made its only documented commercial voyage while being towed as a barge from New Orleans to the Sabine River, where it was to be dismantled. Shortly after entering the Gulf, an undiagnosed internal explosion forced the seven-man crew to cut loose their tow and abandon ship. The crew was picked up by the Bisso Company towboat *Barranca*, and *Castine* sank at its current location within about 20 minutes (*New Orleans Item* 1924; Steamboat Inspection Service n.d.).

4.2.2 Archival Research

Prior to this study, a considerable amount of archival research into the construction, use history, and wrecking event of *Castine* had already been completed for two previous investigations of the vessel (Enright et al. 2006; Jones 2007). Therefore, comparatively little time was spent on further research during the 2008 archival trip, in favor of maximizing time spent researching the other study wrecks. A few previously undiscovered documents, however, were located during the trips to the Mariners' Museum and National Archives.

4.2.2.1 Mariners' Museum

Several photographs of *Castine* are catalogued in the Ted Stone Photograph Collection. These include some images that were previously acquired (Enright et al. 2006; Jones 2007), as well as others that were not part of PBS&J's collection. One of these is a profile image of *Castine* at an unknown location (Figure 26), and another showing *Castine* docked alongside the submarine *Viper* during the gunboat's career as a sub tender (Figure 27).

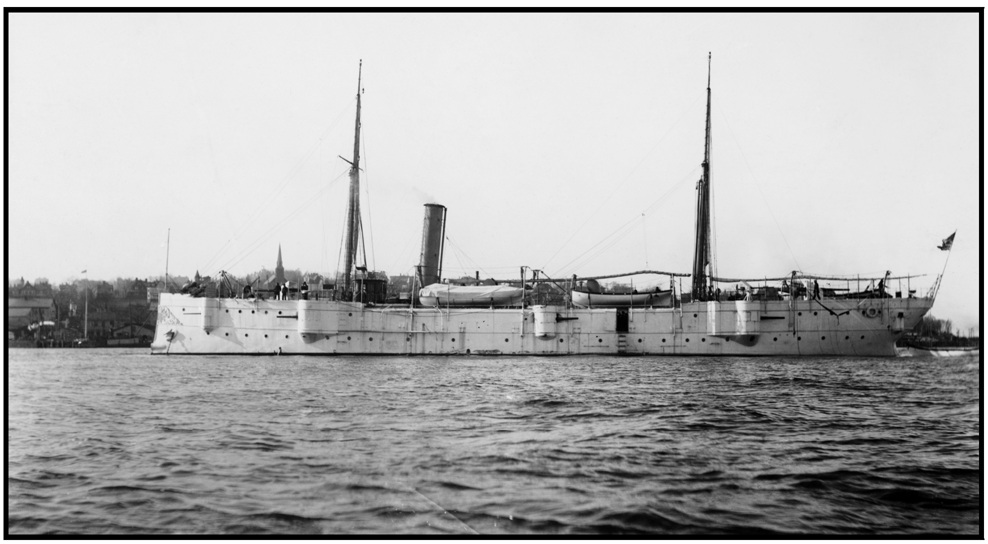


Figure 26. USS *Castine* (Image PN881, Ted Stone Photograph Collection, Mariners' Museum).

Another set of photographs is bound in a scrapbook of East Coast shipyards (Swanton 1994). These images include exterior photographs of both *Castine* and *Machias* docked at Bath Iron Works. Since these photographs were very similar to others already in possession, no copies were obtained.

Figure 27. USS *Castine* submarine *Viper* (Uncatalogued image, Ted Stone Photograph Collection, Mariners' Museum).

4.2.2.2 National Archives

At the National Archives Cartographic Branch in College Park, Maryland, PBS&J searched the Record Group (RG) 19 (Bureau of Ships) Alpha Series ship plans, and the RG19 Dash Series index cards. The Alpha Series contained five ship plans dating between 1909 and 1914, each of which were similar, or in some cases identical, to *Castine* plans that PBS&J had previously obtained. The Dash Series indexes contained over 100 separate *Castine* plans; however, only 10 plans could be requested during any one of the four daily scheduled document retrieval periods. Due to time constraints, only one set of 10 was inspected. These plans included several drawings of *Castine*'s Howell torpedo tube, sail plans, midship section plans, and proposed and/or completed alterations to the upper decks. None of the selected plans illustrated information that was particularly useful to the present study or that had not been previously recorded by PBS&J, although a future trip to inspect all of the 100 catalogued plans may be a worthwhile research objective for continued documentation of this NRHP-eligible vessel.

The RG19 photograph collection was also inspected, but no images previously uncollected by PBS&J were present.

4.2.2.3 U.S. Coast Guard (USCG)

A letter was sent to the USCG National Vessel Documentation Center requesting any available information on *Castine*, specifically relating to the vessel's commercial career from 1921 to 1924 (including owners, insurers, inspection reports, hull characteristics, conversions, and the wrecking event). No information was available in the USCG's records (Martin 2008).

4.2.3 Previous Investigations

Thales Geosolutions' initial remote-sensing data recorded a 170-x-30-ft (51.8-x-9.1-m) sonar target lying flush with the mudline in 105 ft (32.0 m) of water (Floyd 2001) that was speculated to be a modern shipwreck. During the 2005 investigation to determine the site's NRHP eligibility, PBS&J conducted a remote-sensing survey of the site, followed by diver-conducted recording of the vessel's dimensions and hull characteristics, temporary recovery and photographing of a small number of artifacts, and Remotely Operated Vehicle (ROV) videography of selected site features.

The 2005 sonar imagery showed an approximately 220-x-32-ft (67.1-x-9.8-m) vessel with a maximum vertical relief of 20 ft (6.1 m). Only a single deck was visible, though there were pronounced vertical features extending above the deck at the bow and stern (Figure 28). Numerous open hatchways were spaced along the deck, as well as what appeared to be corrosion holes exposing the underlying deck beams. Symmetrical features later identified as gun sponsons could be seen protruding outboard from the deck. Diver investigation confirmed much of the sonar data. Several hatches of varying dimensions were spread around the deck, as were covered and uncovered coal scuttles. The poop deck and majority of the forecastle deck had been removed (presumably when the ship was being converted to a barge), along with the riveted steel side-shell that extended above the midsection of the main deck, leaving only a few upper frames and outer hull plating above the main deck at the bow and around the rounded transom. The main deck was littered with netting, machinery, steam pipes, and miscellaneous debris, much of it believed to be intrusive. A large vertical rupture in the hull was observed just to the port side of the stern, but otherwise the hull appeared to be intact. It was inconclusive whether the rupture was a result of the wrecking event or postdepositional.

Through a combination of the archaeological investigation and subsequent archival research, Site 15170 was positively identified as the wreck of *Castine*. The site was nominated for listing in the NRHP in 2006, and in 2009 the Keeper of the Register concurred that *Castine* is eligible for listing.

4.2.4 2007 Remote-Sensing Survey

Castine was surveyed again in May 2007 for the present study. Comparison of the sonar imagery to the 2005 data showed no discernible post-Katrina impacts to the site (see Figure 28). There had been no positional displacement of the hull nor any indications of structural damage. Water depths remained at prestorm levels (ca. 100 ft [30.5 m] to the top of the wreck and 115 ft [35.1 m] at the surrounding seabed), and there were no signs of sediment accumulation on or around the wreck. Despite the absence of any indicators of hurricane-induced site impacts, PBS&J recommended further diver investigation of *Castine* on the basis that it was the closest of any of the selected wrecks to Katrina's path, and, therefore, had the highest likelihood of sustaining hurricane-related impacts.

4.2.5 2007 Diving Investigations

Nine dives were attempted on *Castine* over two days in October 2007, with limited results. Shortly before PBS&J's arrival on-site, a weather system producing 10-ft (3.0-m) seas passed westward over the area resulting in increased bottom currents and substantial sediment suspension in the water column. While surface conditions were initially favorable, strong currents, zero visibility, and the limited no-decompression dive times hampered diving efforts. Some useful information was obtained, however. Divers working near the stern noted the remnant framing for the poop deck, spaced on 2-ft

(0.6-m) centers. This observation confirms the theory presented in Enright et al. (2006) and Jones (2007) that the poop deck itself and outer hull plating at this area have been removed. Divers also noted that the stern deck was virtually free of debris, contrasting what was recorded in 2005 (albeit on other areas of the deck). Additionally, approximately 30 ft (9.1 m) aft of amidships on the port side, *Castine*'s deck was observed to be approximately 6 ft (1.8 m) above the seafloor. This is also in contrast to the 2005 investigation, where deck elevations at the bow exceeded 10 ft (3.0 m) above the seafloor in other areas. However, the bow area is known to contain partial remains of the forecastle deck, which may account for the differences in exposed hull elevations.

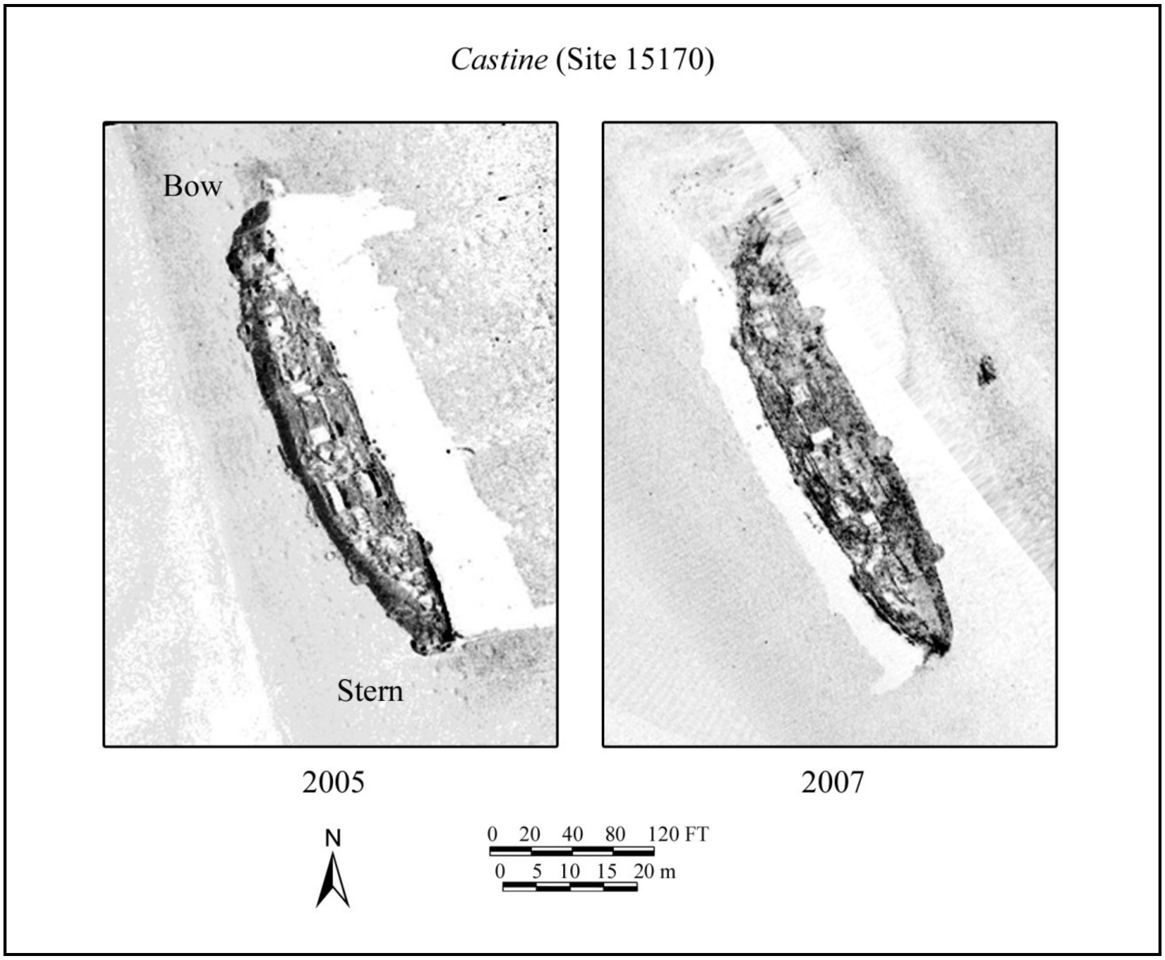


Figure 28. Pre- and posthurricane sonar imagery of *Castine*.

During the diving cruise, additional acoustic imagery of *Castine* was collected with a DIDSON acoustic camera and BOEMRE's sector-scan sonar. No significant structural impacts were observed in this imagery, confirming the side-scan sonar analysis. The sector-scan imagery shows several areas of debris on the seafloor, within 10–15 ft (3.0–4.6 m) of the port side of *Castine*'s hull (Figure 29). However, these areas were never investigated by divers and thus cannot be conclusively linked to hurricane impacts.

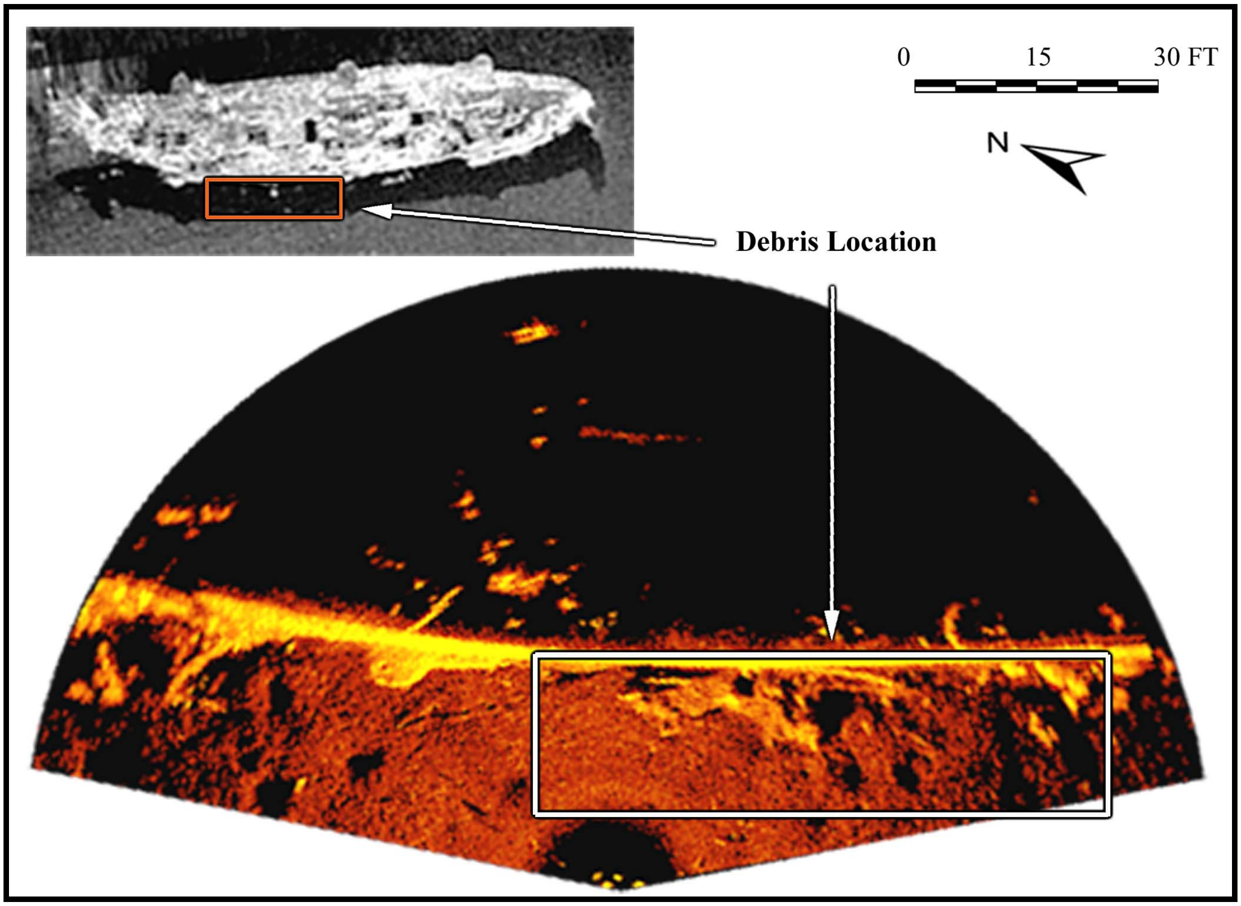


Figure 29. Sector-scan sonar image of *Castine* showing scattered debris on the seafloor.

By the second day of diving, surface conditions had deteriorated considerably, creating an increasingly unsafe diving environment. The decision was made to cease diving operations at *Castine* and continue on to the next selected site.

4.2.6 Sedimentology

For safety reasons, the box core collection device had to be jettisoned during the sediment collection dive on *Castine* (the third site visited during the cruise). Nevertheless, a sediment sample was obtained from sediments that adhered to the dive boat's anchor. The results of that sample's particle-size analysis are presented in Table 10.

Table 10

Castine Particle-size Results

Sample	Provenience	% Gravel	% Sand	% Silt	% Clay	Mean phi	Classification
1-*Castine*	Off *Fling* anchor	0	38	22	7	5.24	Medium silt

Though few conclusions can be drawn from this limited sample, the available data do correspond with mapped soil characteristics for the area. According to maps published by McClelland Engineers

(1979:Plate 2B), Pleistocene soils formed under subaerial conditions during the Late Wisconsin glacial period are roughly 150 ft (45.7 m) beneath the modern mudline in the vicinity of *Castine*. In other words, all of the sediments affecting or affected by *Castine* or the passage of hurricanes are submarine Holocene deposits.

McClelland Engineers (1979:Plates 3B, 4B, and 5B) mapped the shear strength of soils from the seabed to a depth of 20 ft (6.1 m) in the range of 0.4 to 0.8 kilopounds per square foot (ksf), which they qualitatively describe as soft to firm in the vicinity of *Castine*. The Offshore Technology Research Center (OTRC) of Texas A&M University updated McClelland Engineers' shear strength data for the Western and Central GOM in a 2004 study (Dunlap et al. 2004). Their maps depict shear strengths at the mudline, 5 ft (1.5 m) below the seafloor, and 10 ft (3.0 m) below the seafloor. The shear strength data at the mudline are interpolated from data collected at deeper depths. Two methods were used for mapping the data: (1) interpolated shear strength constructed using the spline method, which contours the data without regard to bodies of cohesionless sediment (i.e., sand or silt); and (2) interpolated shear strength taking into account bodies of cohesionless sediment (using sand polygons as barriers that contours cannot cross). Due to a paucity of coring data, method 2 created numerous artifacts in their data presentation.

The OTRC map constructed using method 1 shows soil shear strengths surrounding the location of *Castine* as 1.2 ksf (stiff) at the mudline, 0.2 ksf (soft) at 5 ft (1.5 m) below the seafloor, and 0.4 ksf (soft) at 10 ft (3.0 m) below the seafloor. The map constructed using method 2 indicates a shear strength of 0.4 ksf (soft) at the mudline, 0.5 ksf (soft) at 5 ft (1.5 m) below the seafloor, and 1.4 ksf (stiff) at 10 ft (3.0 m) below the seafloor. The OTRC's study includes only two data points within 10 mi (16.1 km) of *Castine*'s location, therefore, the data are highly interpolated at the wreck site.

There was no indication in the sonar data or in the limited diving investigations that the wreck has experienced increase burial relative to the prestorm study. Furthermore, sonar data indicate several areas of debris deposited immediately adjacent to *Castine*'s hull. Whether these debris piles pre-dated or were a result of Katrina is unknown, but in either case their visibility since the hurricane indicates that soil shear strengths were high enough to prevent burial of these objects.

4.2.7 Impact Assessment

Hurricane Katrina passed 30 mi (49 km) east of *Castine* as a Category 3 storm at about 4 A.M. on August 29, 2005. Peak sustained winds over *Castine* were estimated by Oceanweather, Inc.'s (2006) hindcast model at 74 mph (32.9 m/s) from a direction of 289 degrees. The maximum significant wave height over *Castine* was estimated at 32 ft (9.8 m) from a direction of 128 degrees. Wind speed was not used in modeling the wave-current interaction; it is provided here mainly to demonstrate that the direction of strongest winds in a hurricane is often significantly different than the direction of the largest waves and currents. The largest waves and swiftest currents, on the other hand, share a common direction.

At peak storm conditions over the site, maximum bottom currents of 5.8 mph (2.6 m/s) struck *Castine's* hull along the starboard side from nearly astern of the vessel at an angle of 8 degrees relative to the ship's orientation. Given the difference in density between seawater and air, the damage potential represented by this water velocity is equivalent to that of a 164-mph (73-m/s) wind. At intervals of 8.2 seconds, the current reversed direction 180 degrees beneath the wave troughs to a velocity of –2.9 mph (–1.3 m/s), then peaked again 8.2 seconds later at 5.8 mph (2.6 m/s) in the forward direction beneath the next wave crest. This sloshing effect has been likened to that of a washing machine, although the analogy of an F3 tornado presented in Chapter 3 might be more accurate in terms of scale and damage potential. The amplitude of velocity change from forward to reverse on an interval of 8.2 seconds was 8.7 mph (3.9 m/s).

The extent of hurricane-induced impacts to *Castine* is inconclusive at this time. The remote-sensing data show no significant alterations to the site since the latest prestorm survey; however, divers and sector-scan sonar recorded circumstantial evidence of minimal site impacts. The stern deck was largely clear of debris, yet areas on the seafloor adjacent to the port side of the wreck forward of the stern showed indications of possible increased debris accumulation. The concentration of debris within 15 ft (4.6 m) of the wreck on its port side implies that it likely was not the result of randomly deposited intrusive debris, but rather that it had at one point been positioned on the vessel's deck and subsequently migrated off, possibly during Hurricane Katrina. Such a conclusion is consistent with the direction of the strongest currents across the site.

These debris piles were not evident in the May 2007 side-scan sonar data, because the port side of the wreck was obscured by the sonar shadow. The 2005 side-scan data evinces some debris on the port side, albeit to a lesser extent than is evident on the 2007 sector-scan imagery. Direct comparison with the 2005 sonar data is also inconclusive however, since the MS1000 sector-scan data were recorded at a closer range and higher resolution than were either the 2005 or 2007 side-scan sonar data, which may account for some of the differences in visible objects on the seafloor. Furthermore, only a small section of the stern deck was observed to be relatively free of debris. Divers were unable to investigate the forward sections of the deck to see if they were similarly cleared of loose debris.

4.2.8 National Register Assessment

Castine was recommended as eligible for the NRHP following its investigation and identification in 2005 (Enright et al. 2006). The site was subsequently nominated for NRHP inclusion, and the Keeper of the Register subsequently concurred that *Castine* was eligible for listing (USDOC, NPS 2009). Eligibility status was granted prior to any analysis of posthurricane site impacts; however, that analysis has shown that there has been no significant alteration of site conditions. PBS&J recommends that *Castine*'s NRHP eligibility status remain unchanged from previous assessments.

4.3 Site 323

Site 323 is located in the East Cameron lease block area, 28.5 mi (45.9 km) east of Hurricane Rita's path. This was the only selected wreck located on the more powerful eastern side of a hurricane. The strongest winds over the site during Rita's passage, estimated from hindcast data, were estimated at 86 mph (38.4 m/s), and peak significant wave height was estimated at 30.8 ft (9.4 m). Site 323 measures approximately 200 ft (61 m) long by 35 ft (10.7 m) wide and was first discovered in approximately 70 ft (21.3 m) of water during a survey of the East Cameron lease block area for Apache Corporation in 1994 (Trabant 1994). In 2004 the site was investigated by PBS&J as part of a study to conduct NRHP evaluations of submerged sites on the GOM OCS (Enright et al. 2006).

4.3.1 History

Based on hull characteristics, Site 323 is believed to be a modern offshore supply boat associated with the GOM oil and gas industry.

Multiple inquiries into Site 323's specific identity have been made since PBS&J first visited the site in 2004. The results of those inquiries are presented below; however, at this time the identity and history of Site 323 remains unknown.

4.3.2 Archival Research

During the 2004 NRHP evaluation (Enright et al. 2006), PBS&J inspected several shipwreck databases and published shipwreck lists including the BOEMRE Archaeological Resource Information (ARI) database, NOAA's Automated Wreck and Obstruction Information System (AWOIS), the Louisiana Division of Archaeology's (LDA) Shipwreck List, and the annual list of merchant vessels lost, published in the *Merchant Vessels of the United States* (*MVUS*) (U.S. Bureau of Customs 1958–1967; U.S. Dept. of Transportation, Coast Guard 1968–1989). Using these sources PBS&J compiled a list of reported wrecks within 20 mi (32.2 km) of Site 323. Each of these wrecks was cross referenced against its listing in the *MVUS* to determine hull type and dimensions. Based on these criteria, all of the suspect wrecks were ruled out as the identity of Site 323, including the 102-ft-long (31.1-m) tugboat *Edgar F. Coney* (reported foundered 18 mi (29.0 km) northwest of Site 323 in 1930), and the 130-ft (39.6-m) oil screw *Lafourche* (reported lost in 1971, approximately 3 mi (4.8 km) southeast of Site 323), both of which had been listed in the ARI as possible matches for the wreck. Unable to determine the wreck's identity at the time, PBS&J deemed its NRHP eligibility inconclusive.

Because the identity of Site 323 remains unknown, it was difficult to efficiently direct research objectives during the additional archival research conducted in 2008. Searching the archival record for an anonymous supply vessel that wrecked sometime in the last 50 years is like searching for the proverbial needle in a haystack and would have taken already limited time away from researching the other wrecks of known identity. The only recourse was to attempt to work backwards from the wrecking event by checking USCG records for reported wrecks in the vicinity of Site 323. A Freedom of Information Act letter of request was filed with the USCG Sector New Orleans for any information corresponding to a wrecked vessel matching Site 323's dimensions and hull type and in the East Cameron vicinity (Jones 2008). The request was passed on to the USCG Waterways Division and the District Wrecks and Obstructions Coordinator, neither of which was able to locate any information pertaining to Site 323 (Bullock 2008). The District Wrecks and Obstructions Coordinator checked the USCG database for any wrecks within 20 mi (32.2 km) of Site 323 and found no reported wrecks over 100 ft (30 m) long (Ledet 2008, 2009).

The first offshore oil well was drilled in the GOM in 1947, and, initially, converted fishing boats and retired World War II vessels were used as supply boats. The first purpose-built supply boat was constructed in 1955 (Offshore Marine Service Association [OMSA] 2010). Based on this history, PBS&J also checked multiple web-based newspaper archives for reports of offshore supply boats or crew boats that wrecked in the GOM between 1955 and 1994. Several vessels matched these search criteria, including the 580-ft (177-m) Liberian freighter *Vainquer,* wrecked March 1969 (*Big Spring Daily Herald* 1969); the 165-ft (50-m) supply boat *Orleans* (BOEMRE Vessel ID 922), lost in April

1975 (*Ruston Daily Leader* 1975a); the 85-ft (26-m) *Cheramie Botrue*, the 130-ft (40-m) *Pegasus* (BOEMRE Vessel ID 350), and *Elmer D. Connor* that all sank on Christmas Day 1975 (*Ruston Daily Leader* 1975b; *Galveston Daily News* 1975); the 100-ft (30-m) *Mary Lynn*, lost in March 1977 (*Playground Daily News* 1977); the 95-ft (29-m) crew boat *El Paso* (BOEMRE Vessel ID 1415), wrecked in December 1977 (*El Paso Herald-Post* 1977); and the crew boat *Laverne Hebert* (BOEMRE Vessel ID 137) that capsized 10 mi (16.1 km) off Matagorda Island in November 1983 (*Galveston Daily News* 1983). None of these vessels match the dimensions of Site 323, with the possible exception of *Elmer D. Connor*, whose dimensions were not listed. This vessel is an unlikely match, however, as it sank alongside a Tenneco Oil Company rig, 30 mi (48 km) south of Vermilion Bay, Louisiana. No other viable identities for Site 323 were discovered in these newspaper archives.

Finally, PBS&J searched an online database that contains construction records of U.S. shipbuilders and other links pertaining to U.S. shipbuilding history (Colton 2009). Within that site PBS&J searched the records of Gulf Coast shipbuilders, active and inactive, to compile a list of Gulf-built offshore supply boats constructed since World War II. That list was further filtered to pursue two separate research objectives. The first was to determine which vessels had a current disposition listed as *Sank*, *Foundered*, *Wrecked*, *Scuttled*, or *Total Loss* (Table 11). Forty-four supply boats matched one of those descriptions, though the location of loss was not always provided. That list was cross-referenced with two other online ship indexes (BoatInfo World 2009; Haworth 2009) and the *MVUS* (U.S. Bureau of Customs 1958–1967; U.S. Dept. of Transportation, Coast Guard 1968–1989) to identify any vessels matching Site 323's dimensions. None of the listed vessels that sank prior to 1994 matched Site 323's description.

The second research objective from the list of postwar Gulf-built vessels was to try to identify any temporal patterns in offshore supply boat dimensions that would further isolate a construction date for Site 323. Again cross-referencing with two online ship indexes (BoatInfo World 2009; Haworth 2009), PBS&J identified 24 offshore supply boats from the list that measured 200–215 ft (61–66 m) long. The earliest of these vessels was *Tidelands*, built by Atlantic Marine, Inc., in 1965, suggesting that supply vessels equal to or greater than 200 ft (61 m) long were not common before that year.

4.3.3 Previous Investigations

The initial 1994 survey by Trabant (1994) recorded an unidentified shipwreck lying in a scour hole in 70 ft (21.3 m) of water. Side-scan sonar data indicated the wreck was approximately 180 ft (55 m) long and 23 ft (7.0 m) wide; the corresponding magnetic anomaly measured 2,100 gammas. In 2004 Site 323 was investigated by PBS&J as part of a study to conduct NRHP evaluations of submerged sites on the GOM OCS (Enright et al. 2006). PBS&J conducted a magnetometer and side-scan sonar survey of the wreck, followed by diver and ROV investigations. Side-scan sonar data confirmed that the vessel was approximately 200 ft (61 m) long and at least 36 ft (9.1 m) wide, and further determined the wreck to be laying keel-up at a slight list to starboard, with twin screws exposed (Figure 30). The diver and ROV investigations noted that the vessel appeared to be modern, with a steel or aluminum hull exhibiting a moderate degree of corrosion and degradation, but otherwise intact. Twin three-bladed propellers with corresponding rudder posts were extant; however, only the starboard rudder remained. Limited visibility under the aft end of the wreck revealed a low, flat deck consistent with design characteristics of a typical offshore supply vessel.

Table 11

Gulf-built Offshore Supply Boats that Have Been Lost

Shipyard	Hull #	Name	Customer	Type	Dimensions	Built	Disposition	BOEM Vessel ID
Halter Marine, Moss Point, MS	188	*Auster*	Auster inc., LA	Supply Vessel	157.9 ft x 38 ft x 11.6 ft	1968	Sank	N/A
Alexander Shipyard	934	*Baroid Ranger*		Offshore Service Vessel	Unknown	1966	Scuttled 1999	N/A
Alexander Shipyard	902	*Beauregard*	Tidewater Grand Isle, Inc, LA	Offshore Service Vessel	154.2 ft x 35 ft x 11.5 ft	1964	Scuttled	N/A
McDermott Shipbuilding, Amelia & Morgan City, LA		*Betty G*		Offshore Service Vessel	Unknown	1963	Scuttled 2001	N/A
Halter Marine, Moss Point, MS	415	*Black Bart*	Euro-Pirates International, Inc.	Anchor-Handling Tug Supply	170 ft	1974	Sank	N/A
Alexander Shipyard	981	*Blue Dolphin*		Fishing Vessel	Unknown	1967	Total loss 1996	N/A
Alexander Shipyard	955	*Brick Tide*	Tidewater Marine	Offshore Service Vessel	160.5 ft x 36 ft	1966	Sank, NE coast of South America	N/A
Alexander Shipyard	622	*C. E. Tide*	Tidewater Marine	Offshore Service Vessel	Unknown	1957	Sank	N/A
Alexander Shipyard	932	*Cheramie Bo-Truc No. 15*	L. & M. Bo-Truc Rentals	Offshore Service Vessel	143.8 ft x 36 ft	1967	Sank	N/A
Alexander Shipyard	1064	*Coral Seahorse*	Zapata Marine	Offshore Service Vessel	Unknown	1971	Total loss 1996	N/A
Mangone Shipbuilding, Houston, TX	94	*Eastern Worker*		Offshore Service Vessel	Unknown	1970	Scuttled 2002	N/A
Burton Shipyard, Port Arthur, TX	396	*El Caballo Grande*	Tidewater Marine	Offshore Service Vessel	Unknown	1966	Sank 2000	N/A
Halter Marine, Lockport, LA	260	*El Jabali Grande*	Tidewater Marine	Anchor-Handling Tug	Unknown	1970	Total loss	N/A
Universal Iron Works, Houma, LA		*El Leon Grande*	Tidewater Marine	Supply Boat	Unknown	1966	Sank 2000	N/A
Halter Marine, Lockport, LA	449	*Evelyn Tide*	Tidewater Marine	Supply Vessel	166 LPP x 38	1974	Sank, Brazil	N/A
Halter Marine, Moss Point, MS	420	*Florida Martin*	AMT Marine	Supply Vessel	170 ft x 38 ft	1974	Sank	N/A
Quality Shipyards, Houma, LA	147	*Gulf Fleet No. 31*	Tidewater Marine	Offshore Service Vessel	180 ft x 38 ft	1978	Wrecked 1985	N/A
Halter Marine, Moss Point, MS	413	*Halliburton 218*		Supply Vessel	165 ft x 38 ft; 2 screw diesel	1973	Sank	
Burton Shipyard, Port Arthur, TX	395	*Huge Tide*	Tidewater Marine	Offshore Service Vessel	154.7 ft x 38.1 ft	1966	Sank	N/A
Burton Shipyard, Port Arthur, TX	300	*Jackson*, Later *Eileen B 1976, Aloha 1977*		Offshore Service Vessel	Unknown	1960	Foundered 2002	N/A
Halter Marine, New Orleans, LA	212	*Joel Robin*		Anchor-Handling Tug	100 ft	1969	Sank 1983	1012
Alexander Shipyard	1086	*Kappa Tide*	Tidewater Marine	Offshore Service Vessel	164 ft x 38 ft	1972	Wrecked	N/A
Halter Marine, Moss Point, MS	330	*Kara Seahorse*	Zapata Marine	Supply Vessel	166 ft x 38 ft	1972	Sank	N/A
Alexander Shipyard	982	*King Tide*	Tidewater Marine	Offshore Service Vessel	Unknown	1967	Total loss 1999	N/A
Halter Marine, New Orleans, LA	1072	*Kodiak II*		Anchor-Handling Tug Supply	225 ft x 52 ft	1983	Sank 1998	1052
Burton Shipyard, Port Arthur, TX	327	*Lena C. Candies*	Otto Candies	Offshore Service Vessel	97.2 ft x 23.3 ft x 9.9 ft	1962	Sank	N/A
Halter Marine, Moss Point, MS	1069	*M220*	Falcon Service	Anchor-Handling Tug Supply	Unknown	1983	Total loss	N/A
Burton Shipyard, Port Arthur, TX	234	*Nancy H*	Hudson Marine	Offshore Service Vessel	124.7 ft x 32.1 ft x 9.5 ft	1956	Sank	N/A
Burton Shipyard, Port Arthur, TX	398	*Nashua*	Thorough Marine	Offshore Service Vessel	95.7 ft x 24.2 ft	1966	Sank	N/A
McDermott Shipbuilding, Amelia & Morgan City, LA	174	*Pam Alario*		Offshore Service Vessel	127.2 ft x 34 ft	1972	Sank	N/A
Burton Shipyard, Port Arthur, TX	525	*Paul Candies*	Otto Candies	Offshore Service Vessel	175 ft x 44 ft	1978	Sank	N/A
Burton Shipyard, Port Arthur, TX	449	*Pisces*	Zodiac Offshore	Offshore Service Vessel	160.8 ft	1970	Sank	N/A
Burton Shipyard, Port Arthur, TX	502	*Polar 901*	Zodiac Offshore	Offshore Service Vessel	217 ft x 44 ft	1973	Sank, possibly on Rio Grande due to fire, 1992	N/A
Burton Shipyard, Port Arthur, TX	521	*Republic Service*	Zapata Marine	Offshore Service Vessel	183 ft x 40 ft	1975	Foundered, 1982	N/A
Alexander Shipyard	1024	*S. A. Levy*		Offshore Service Vessel	167.5 ft x 38 ft	1969	Sank	N/A
Alexander Shipyard	1110	*Salton Seahorse*	Zapata Marine	Offshore Service Vessel	170 ft x 38 ft	1973	Scuttled	N/A
Alexander Shipyard	968	*Search Tide*	Tidewater Marine	Offshore Service Vessel	160.5 ft x 36 ft	1967	Sank	N/A
Alexander Shipyard	848	*South Tide*	Tidewater Marine	Offshore Service Vessel	131.1 ft x 33.1 ft	1963	Sank	possibly Vessel 1442; sank in 218 ft in 1979
Burton Shipyard, Port Arthur, TX	366	*Southern Service*	Sea Services	Offshore Service Vessel	148.4 ft x 38.1 ft	1964	Foundered	N/A
Halter Marine, Moss Point, MS	737	*Stephanie Hebert*		Supply Vessel	162 ft x 38 ft	1978	Sank	N/A
Burton Shipyard, Port Arthur, TX	307	*Tanforan*, Later *Falcon, Petrel, William T* 1983, *Fidel Jr.* 1992		Offshore Service Vessel	141 ft x 34.1 ft	1961	Sank	N/A
Mangone Shipbuilding, Houston, TX	109	*Tender Tarpon*	Wilhelmsen Offshore	Offshore Service Vessel	189 ft x 38 ft	1973	Total loss 1993	N/A
Burton Shipyard, Port Arthur, TX	204	*Tilman J.*	Tilman Offshore	Offshore Service Vessel	95 ft x 25 ft x 10.4 ft	1955	Sank	N/A
Burton Shipyard, Port Arthur, TX	226	*Tilman J. No. 2*	Tilman Offshore	Offshore Service Vessel	124.9 ft x 32.1 ft x 9.5 ft	1956	Sank	N/A

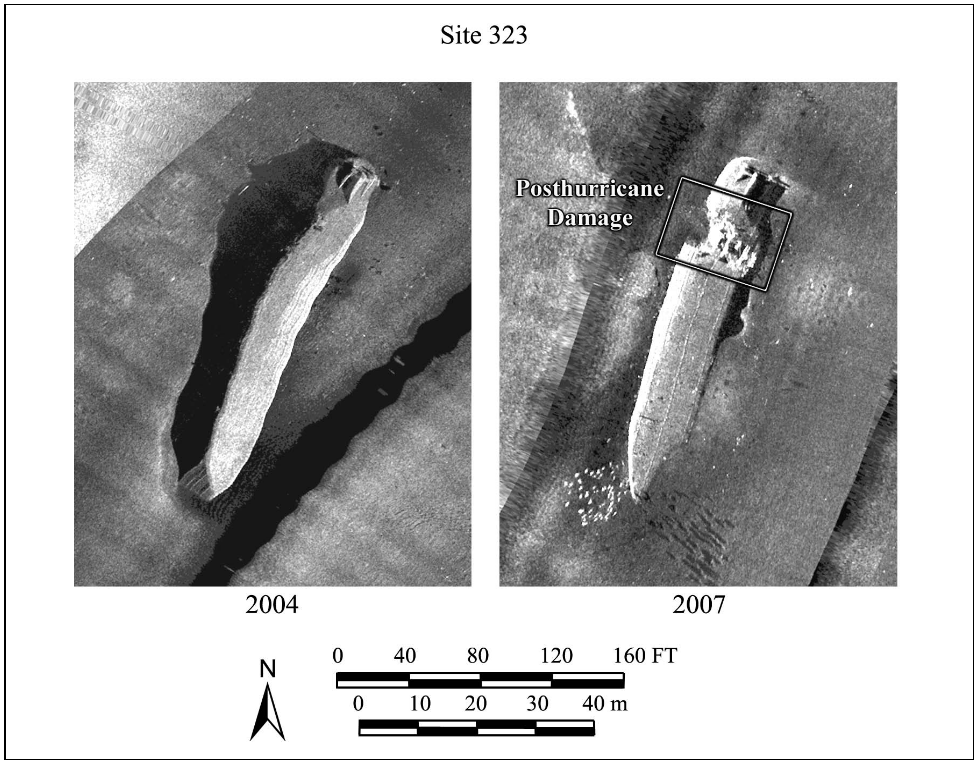


Figure 30. Pre- and posthurricane sonar imagery of Site 323.

In 2006, Geotex Company conducted a high-resolution geophysical survey of the East Cameron lease block area for Remington Oil and Gas Corporation (Geotex Company 2006), including the area surrounding Site 323. Examination of these data for the current study showed that Geotex Company's sonar imagery of Site 323 corresponded closely with PBS&J's 2004 data, with the exception of evidence of extensive hull fractures in the vessel's aft third (Figure 31). These fractures indicated recent exposure to a destructive event, either by external impact or internal structural collapse.

4.3.4 2007 Remote-Sensing Survey

PBS&J resurveyed Site 323 in May 2007 for the present study. The 2007 sonar data confirmed the site damage recorded in Geotex's 2006 survey; an extensive hull rupture was evident near the vessel's stern (see Figure 30). The breakage begins approximately 30 ft (9.1 m) forward of the transom, and extends the full width of the hull. It is widest, 23 ft (7.0 m), at the port gunwale, and tapers to 12 ft (3.7 m) on the starboard side. There is also evidence of increased scouring since 2004, along the starboard edge of the wreck just forward of the broken area, and increased burial of the starboard bow.

Prior to beginning the dive investigation, PBS&J reanalyzed the accumulated sonar data and discovered that there had been subtle evidence of weakened hull structure in 2004 (Figure 32). Though on a much smaller scale than the posthurricane damage, there does appear to be more-pronounced hull degradation over an approximately 10-square-foot (ft^2) (0.9 m^2) area on the port side. This damage was not observed by divers in 2004 and may have been indistinguishable from metal corrosion holes present throughout the exposed vessel hull.

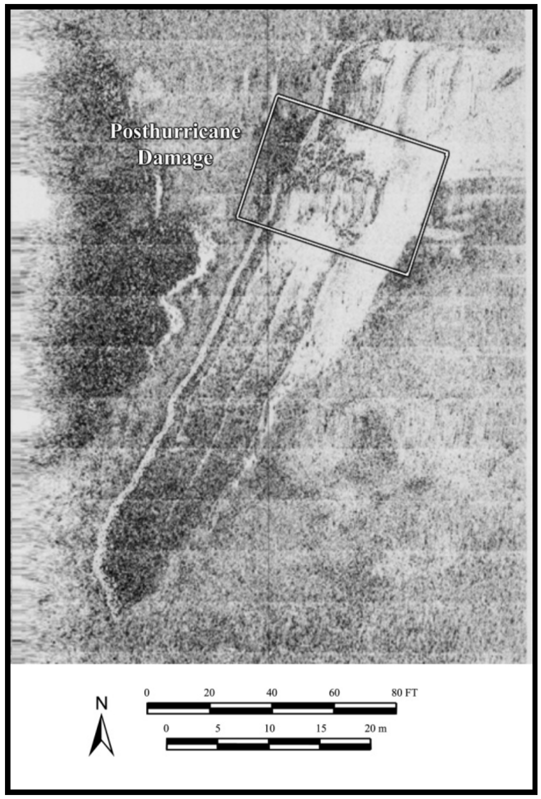


Figure 31. 2006 sonar imagery of Site 323 (image courtesy of BOEMRE).

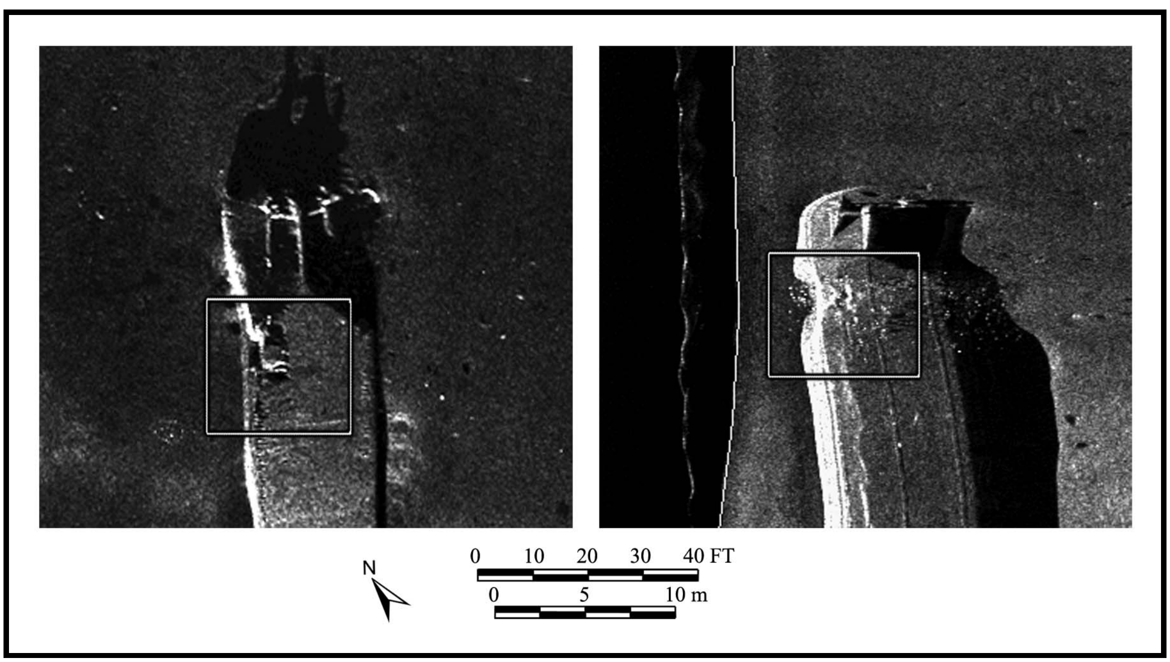


Figure 32. Close-up of 2004 Site 323 sonar imagery showing weakened hull at the stern.

4.3.5 2007 Diving Investigations

Ten dives were conducted on Site 323 in October 2007. Diving objectives were focused on recording the areas of hull damage, attempting to diagnose the cause, and locating diagnostic information that could lead to vessel identification.

The hull rupture was observed to begin at the mudline on the vessel's port side and extend beyond the starboard-side turn of the bilge. The breakage was characterized by collapsed hull plates near the centerline surrounded by broken frames. Moving outward in either direction from the center was extensive broken, twisted, and collapsed hull structure. The nature of the damage appeared random and did not indicate a single impact point from a foreign object or other unidirectional force. DIDSON and sector-scan imagery further confirmed the extent of damage (Figure 33), showing extensive areas of disarticulated hull structure. For safety reasons, no attempt was made to penetrate the wreck to investigate any internal damage in this area.

Further changes to the site since 2004 include removal of the starboard rudder and accumulation of debris adjacent to the hull rupture on the port side. Divers investigating the stern area recorded both propellers and rudder posts still intact; however, the starboard rudder was no longer extant and was not identified on the surrounding seabed. Immediately outside the wreckage, on the port side of the broken area and again about 10 ft (3.0 m) forward, lay a large amount of debris, likely associated with the ruptured hull.

Water depths ranged from 65 ft (19.8 m) at the top of the wreck to 78 ft (23.8 m) at the bottom of a scour depression on the port side. The surrounding seabed averaged about 74 ft (22.6 m) deep. There was a 3 percent rise in hull depth (69 ft to 65 ft [21.0 m to 19.8 m]) from the bow to just forward of the broken area. General observations of the site include both three-bladed propellers, numerous areas of corrosion holes covering the bottom of the hull; 4-inch (10.2-cm) doubled flat-bar steel frames; a partially visible stern deck underneath the port-side gunwale; two rubberized "D"-shaped rub rails running parallel along the vessel perimeter; and a bumper tire attached to the side-hull towards the bow. These features all substantiate the theory that Site 323 is a modern offshore supply vessel or crewboat; however, no identifying features were observed.

4.3.6 Sedimentology

Two box cores were collected at Site 323, one parallel to storm wave propagation (135°) and one perpendicular to wave propagation (45°). Sediment stratigraphy was identical in each of the cores. A hard, oxidized layer, indicated by a dark brown/yellowish color, was present less than a foot beneath the mudline (Figure 34). This surface is believed to be a remnant of the Pleistocene subaerial land surface, known geologically as the Beaumont Formation. Expansive outcrops of this formation were observed on sonar within a few hundred meters of the site (Figure 35).

The box cores were separated into three subsamples based on visible color and/or texture changes, plus an additional sampling of the Pleistocene subaerial surface. Particle-size analysis showed that all subsamples were medium or coarse silt (Table 12). No sand lenses or zones were noted.

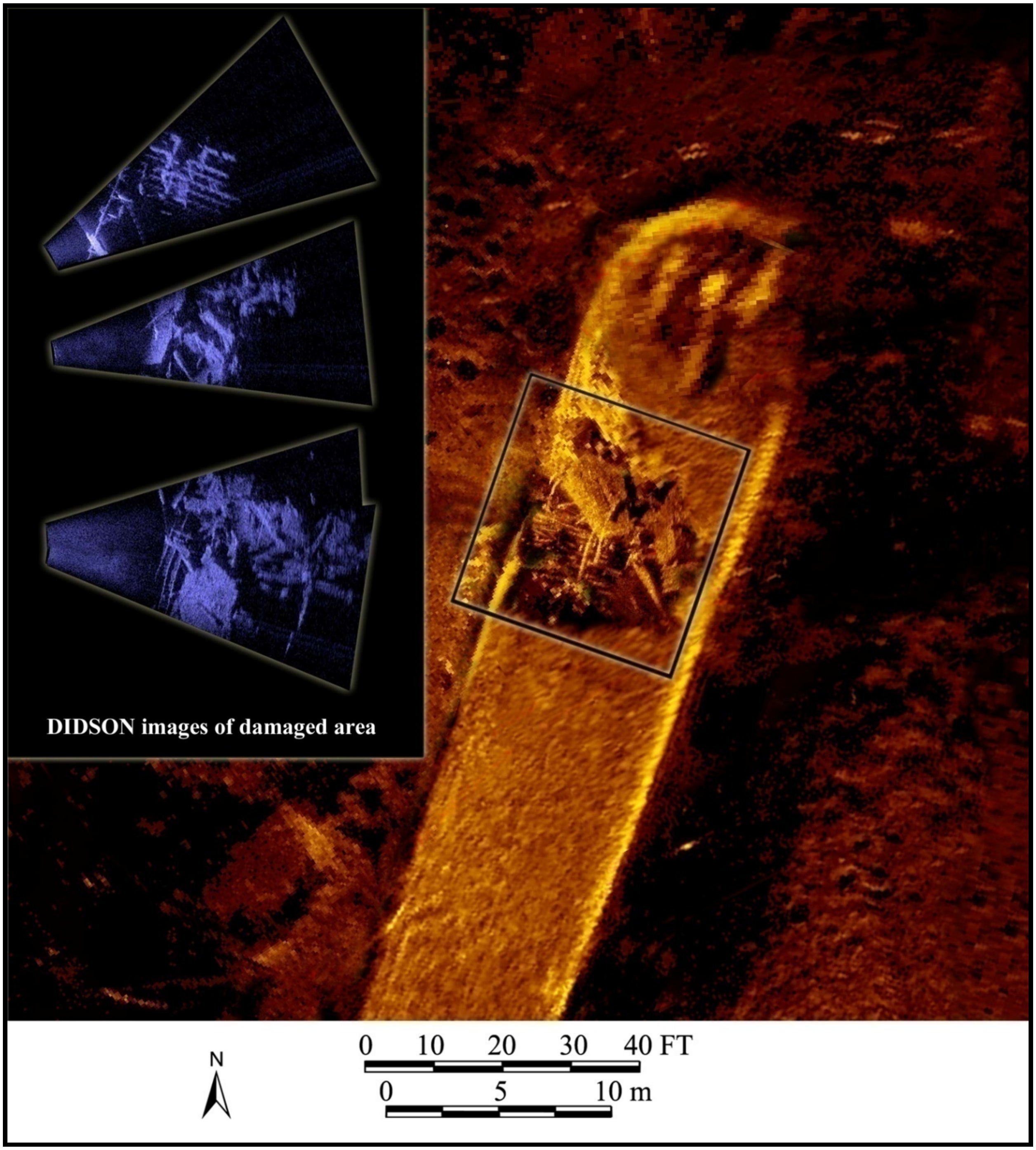


Figure 33. Sector-scan sonar and DIDSON imagery of Site 323 hull damage.

Figure 34. Box core sample from Site 323.

Table 12

Site 323 Particle-size Results

Sample	Provenience	% Gravel	% Sand	% Silt	% Clay	Mean phi	Classification
1-323	0–4 cm below mudline (bml)	0	9	51.1	7	5.67	Medium silt
2-323	4–12 cm bml	3.5	27.5	42	6	4.99	Coarse silt
3-323	12–29 cm bml (oxidized surface)	2	18	58	3	5.16	Medium silt
4-323	Extra Pleistocene mud	0.5	20	61	3	5.15	Medium silt

Though the grain size results are inconclusive as a stand-alone data set, the visible presence of the oxidized Beaumont Formation provides an important interpretive clue. This formerly subaerial Pleistocene surface is extremely firm with a low permeability, and signifies the probable level of maximum wreck subsidence. This, in turn, hints at a contributing factor in the documented damage to Site 323's hull. Areas of the seafloor containing deposits of cohesionless sediments (typically sand) have been shown to increase the probability of shipwreck subsidence through the processes of scour, sediment deposition, bedform migration, or liquefaction (Keith and Evans 2009). Over time, these processes will result in the partial or complete burial of wreck remains, providing a layer of protection against the destructive effects of waves, currents, oxygenation, and biofouling. If these protective sediments are absent or minimized, as is the case at Site 323, then a wreck is left exposed to all of the above destructive processes.

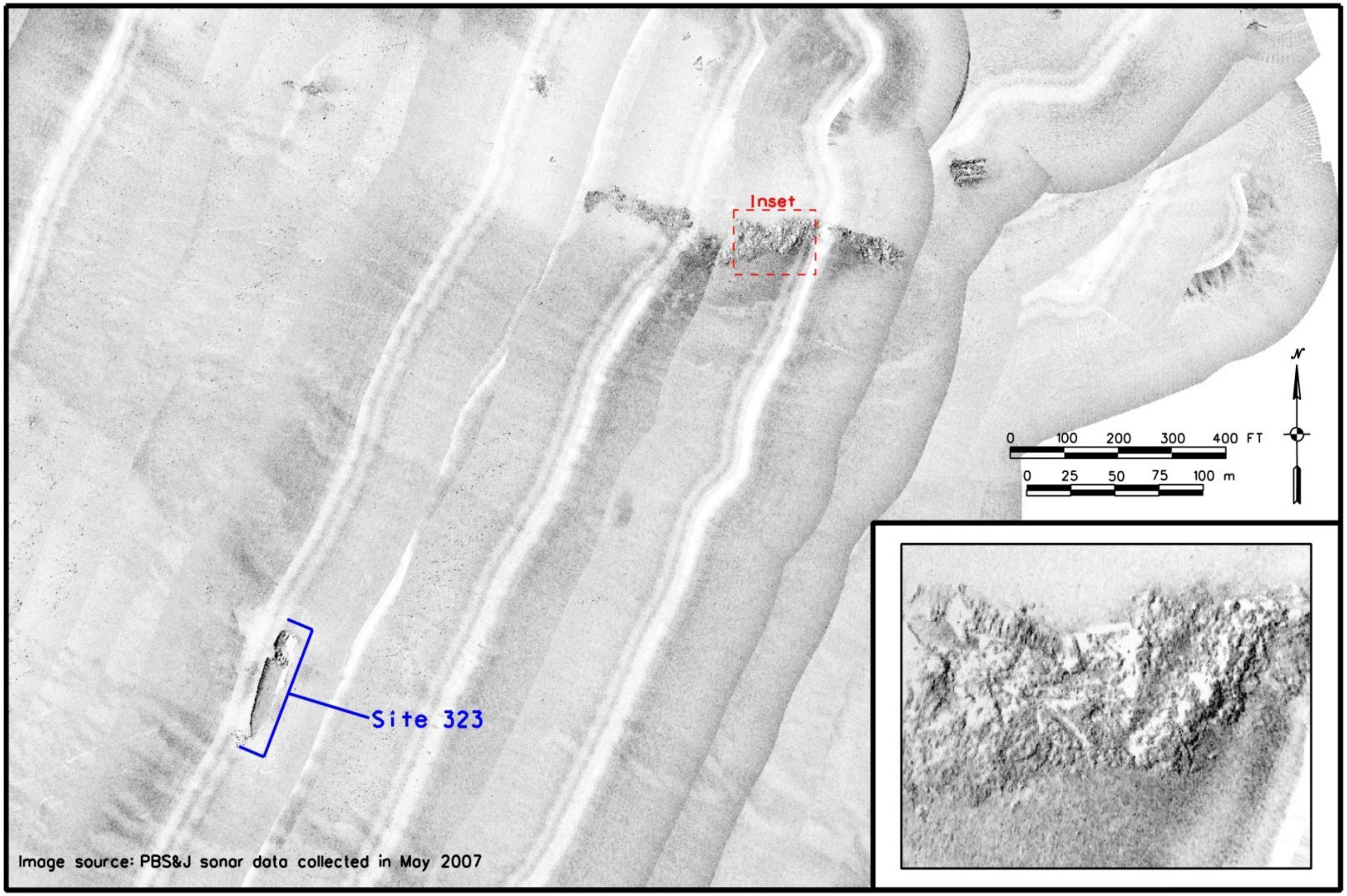


Figure 35. Sediment and Pleistocene clay outcrops in the vicinity of Site 323.

According to maps published by McClelland Engineers (1979:Plate 2A), Pleistocene soils formed under subaerial conditions during the Late Wisconsin glacial period are less than 20 ft (6.1 m) beneath the modern mudline in the vicinity of Site 323. Sonar imagery indicates this site rests on a localized area of granular surface sediments, which are arranged in linear bands paralleling the southern margin of a clay outcrop. The clay outcrop, which begins 1,000 ft (305 m) north of the wreck (see Figure 35), is associated with a diapir (salt dome) that, according to Berryhill et al. (1984:Sheet II), has been subjected to subaerial erosion. A fault curves around the southern side of this diapir (Berryhill and Owen 1984:Sheet III). The downthrown side of the fault is south of the diapir and coincides with the area where sand appears to have accumulated. Berryhill et al. (1984:Sheet II) also indicate two generations of buried Wisconsin-aged stream channels crossing near Site 323 south and east of the site, although neither one is believed sufficiently close to underlie the hull.

McClelland Engineers (1979:Plates 3A, 4A, 5A) map the shear strength of soils in the vicinity of Site 323 from the seabed to a depth of 20 ft (6.1 m) in the range of 0.8 to 1.0 ksf, which they qualitatively describe as firm. The OTRC (2004) map constructed using method 1 (see description in *Castine* sedimentology results, Section 4.2.6) shows soil shear strengths surrounding the location of Site 323 as 0.2 ksf (soft) at the mudline, 1 ksf (stiff) at 5 ft (1.5 m) below the seafloor, and 0.5 ksf (soft) at 10 ft (3.0 m) below the seafloor. According to the OTRC maps, Site 323 is located within an area of sand deposits from the mudline to 10 ft (3.0 m) below the seafloor, meaning their shear strength map constructed using method 2 did not calculate shear strengths in the area of Site 323. OTRC's data showing large deposits of sand in the vicinity of Site 323 did not match PBS&J's box core results for the top 1 ft (0.3 m) of sediment (see Table 12); however, OTRC's closest data point was approximately 5 mi (8.0 km) from the site location, and it did not record sand. The presence of the nearby diapir, combined with the observed Pleistocene sediments adjacent the wreck, indicate that OTRC's data interpolation for areas of sand coverage is inaccurate at Site 323's exact location. The highly cohesive underlying sediments imply that localized soil shear strengths are low. Accordingly, the probability of increased site subsidence from Hurricane Rita, or from any future natural events, is expected to be low.

4.3.7 Impact Assessment

Hurricane Rita passed 28.5 mi (45.9 km) west of Site 323 as a Category 3 storm at 9:30 P.M. on September 23, 2005. Peak sustained winds over Site 323 were estimated by Oceanweather's (2006) hindcast model at 86 mph (38.3 m/s) from a direction of 125 degrees. The maximum significant wave height over Site 323 was estimated at 30.8 ft (9.4 m) from a direction of 191 degrees. At peak storm conditions over the site, maximum bottom currents of 7.6 mph (3.4 m/s) struck Site 323's hull along the starboard side bow (the hull is inverted) at an angle of 9 degrees relative to the ship's orientation. At intervals of 8.0 seconds, the current reversed direction 180 degrees beneath the wave troughs to a velocity of –2.7 mph (–1.2 m/s), then peaked again 8 seconds later at 7.6 mph (3.4 m/s) in the forward direction beneath the next wave crest. The amplitude of velocity change from forward to reverse on an interval of 8.0 seconds was 10.3 mph (4.6 m/s). Given the difference in density between seawater and air, the damage potential represented by the maximum forward water velocity is equivalent to that of a 215-mph (96.1-m/s) wind or analogous to an F5 tornado.

Site 323 experienced the most-extreme conditions of any of the selected wrecks. The resulting impacts were most pronounced near the stern, where a preexisting area of structural weakness collapsed after being exposed to such dynamic forces. Sections of the steel hull were broken, twisted, collapsed, and bent in all directions in a manner consistent with the violent, multidirectional forces that would have been present during Hurricane Rita. The wreck's keel-up orientation likely contributed to the extent of structural collapse. With the wreck upside down in an unstable position, hurricane forces would be more unevenly distributed around the hull than if the vessel was sitting on its keel. The pilothouse or any other superstructure present on the underside of the wreck may have acted as a fulcrum point, allowing unsupported sections of the vessel to be subjected to repeated upward and downward vertical displacement in the water column caused by the cyclical pressure change of passing waves (see Figure 22). If exposed to such forces over a long enough period of time, the collapse of weakened structural elements would be expected.

The site's vulnerability to damage from hurricane-force conditions may have been further exacerbated by its placement on the oxidized, densely compacted Beaumont Formation. This dense Pleistocene layer, less than a foot beneath the mudline, would limit settlement (i.e., stabilization) of the wreck into the seabed, thus contributing to the damaging structural effects of violent and repeated vertical hull displacement.

Though peak storm conditions at Site 323 were relatively harsh, petroleum industry damage in the area was limited. According to GIS data provided by BOEMRE, no damage was reported to the nearest pipeline, 1.1 mi (1.8 km) west of Site 323. The closest damaged pipeline was one owned by Newfield Exploration Company, 10 mi (16.1 km) south of Site 323, which reported only a bent riser.

4.3.8 National Register Assessment

Site 323 was subjected to an NRHP evaluation study in 2004. Archival research for that study was successful in ruling out several reported possibilities for the wreck's identity, but not in identifying alternate candidates. The resulting report deemed the wreck's eligibility status inconclusive based on insufficient information regarding the vessel's history (Enright et al. 2006). Additional archival research for the present study was also unsuccessful in identifying viable candidates for the wreck's identity. However, several diver observations during the 2007 fieldwork, such as the "D"-shaped rub rails and attached bumper tire, supported Enright et al.'s supposition that Site 323 is likely an offshore supply boat. Since the build date of the vessel is unknown, the possibility remains that it is an early example of a vessel type that was built specifically for oil and gas activities in the GOM. Accordingly, it is potentially eligible for the NRHP under Criterion C: *embodies the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic value, or that represent a significant and distinguishable entity whose components may lack individual distinction*. Furthermore, the as-yet-unknown identity and vessel history of Site 323 also leave open its potential NRHP eligibility under Criterion A: *associated with events that have made a significant contribution to the broad patterns of our history*; or B: *associated with the lives of persons significant in our past.* Until the vessel identity of Site 323 can be resolved, PBS&J recommends that the site's NRHP eligibility status remain inconclusive.

4.4 *Gulf Tide*

Gulf Tide (BOEMRE vessel ID 417) is located in the West Cameron lease block area, 8.4 mi (13.5 km) west of Hurricane Rita's path, making it the closest of any selected wreck to either of the 2005 hurricanes. The strongest winds estimated over the site during Rita's passage were 79 mph (35.3 m/s), and peak significant wave height was estimated at 22.6 ft (6.9 m). The site was first recorded in 1997, when Racal Inc. surveyed a portion of the West Cameron lease block area for IP Petroleum Co., Inc (Racal Inc. 1997).

4.4.1 History

Gulf Tide was a pipeline dredge of unknown dimensions that sank due to “marine casualty” on September 28, 1947 (AWOIS Record 362). According to contemporary USCG reports, the vessel wrecked in 50 ft (15.2 m) of water with its bow resting on the bottom and “about 13.1 mi [21.1 km] and 164 degrees off the Sabine Bank Light” (*Galveston Daily News* 1947). The vessel was identified as foreign and believed to be Argentinean. A USCG Notice to Mariners issued on October 11 reports that *Gulf Tide*’s bow was awash and that the site had been marked (200 yards [183 m] away) with a lighted red and black bell buoy (U.S. Hydrographic Office 1947a). A second Notice to Mariners, issued a week later, reports that the wreck buoy had been repainted all red, and named “Dredge Gulf Tide,” and that “no part of the wreck is now visible above water” (U.S. Hydrographic Office 1947b). In 1948 it was reported that the wreck had “broken up” and was covered by more than 40 ft (12.2 m) of water (AWOIS Record 362).

No further information on *Gulf Tide*’s construction, use history, or cause of sinking have been located; however, if the identification of *Gulf Tide* as a pipeline dredge is accurate, then it can be expected to be a cutterhead-type dredge. Cutterhead dredges are the most commonly used type in the United States due to their efficiency and versatility in excavating a wide range of materials including clay, silt, sand, gravel, and densely packed sediments and soft rock (USACE 1983). They are characterized by two stern spuds; a forward cutterhead, intake pipe, and retractable ladder; the A-frame; and a material discharge pipeline that extends from the stern for distances up to 3 mi (4.8 km) (Figure 36). Most cutterhead dredges are designed to operate in calm water, though some offshore models can operate in up to 6 ft (1.8 m) waves. Because the dredging ladder on which the cutterhead and intake pipes are mounted is rigidly attached to the dredge hull, excessive waves can force the dredge head into the sediment, causing shock-induced damage to the vessel and equipment.

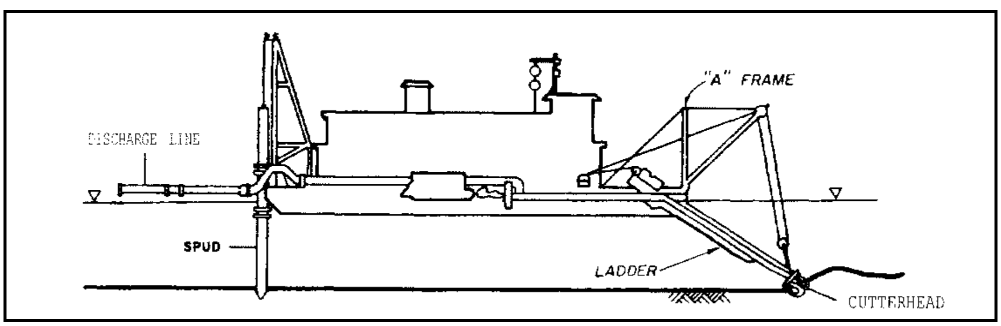


Figure 36. Configuration of typical cutterhead dredge (USACE 1983).

4.4.2 Archival Research

4.4.2.1 Mariners’ Museum

The vessel history files of the Elwin M. Eldredge Collection contain only a single entry for a *Gulftide* (one-word spelling), but it was a 430-ft-long (131-m) tanker built in 1937 for Gulf Oil Corp.

Photographs of this vessel in the Mariners' Museum photo collection confirmed that it is not the dredge *Gulf Tide.*

4.4.2.2 Library of Congress

The Library of Congress contains several volumes of the *Index to Notices to Mariners* (U.S. Hydrographic Office 1947a, 1947b), including the various entries pertaining to *Gulf Tide.* These notices are the source for, and essentially identical to, the information presented in the AWOIS database (Record 362). No other information pertinent to *Gulf Tide* was identified at the Library of Congress.

4.4.2.3 National Archives

At the time of PBS&J's archival research trip, *Gulf Tide*'s Argentinean origin was unknown (*Galveston Daily News* 1947). Therefore, research was conducted on the assumption that *Gulf Tide* was an American-flagged vessel. The resulting records search identified only listings for the previously mentioned tanker *Gulftide* in the *MVUS*, along with a dredge *Gulf Stream* that appears in the *MVUS* from 1938 to 1944. A Certificate of Enrollment from January 11, 1944, notes that *Gulf Stream* was sold to the Navy, Office of Superintending Civil Engineer, New Orleans, in October 1944. This New Orleans location raised the suspicion that *Gulf Tide* may have been the misreported wreck of *Gulf Stream*, and further research was directed towards confirming or refuting this suspicion. In addition to register and enrollment records (RG41: Bureau of Marine Inspection and Navigation, Official No. Files, 1867–1958), multiple Navy records collections were inspected including RG19: Bureau of Ships (ship plans, correspondence, and photographic collection), RG71: Bureau of Yards and Docks (Naval property case files 1941–1958, circular letters 1940–1945, and miscellaneous correspondence), and the *Dictionary of American Naval Fighting Ships,* which identified the Navy's hull designation for *Gulf Stream*: YM-20. This research yielded only ship plans of dredge YM-22 (U.S. Bureau of Ships 1951a, 1951b), which were photocopied in the hope that YM-22 shared design and construction characteristics with *Gulf Stream*/YM-20. A copy of a 1943 photograph of dredge YM-09 (Bureau of Aeronautics 1943; Figure 37) was obtained for the same reason.

After the archival research trip was completed, PBS&J located a contemporary newspaper article that reported the wreck of *Gulf Tide* and tentatively identified it as an Argentinean pipeline dredge (*Galveston Daily News* 1947). This information was relayed to an archivist at the National Archives and Records Administration (NARA) who cross referenced it with the Official Number Files (RG41) and records of the USCG (RG26), specifically Merchant Vessel Information, Station History Files, and Assistance to Vessels Records. None of these documents contained information on *Gulf Tide.*

4.4.2.4 Additional Research

PBS&J also contacted Lloyd's Register, London, to determine if the international company had ever registered the foreign-flagged *Gulf Tide*. Lloyd's confirmed that no vessel matching *Gulf Tide*'s description was recorded in either *Lloyd's Register of Ships* from 1945 to 1951 or in their *Wreck Returns* records (Bloomfield 2008).

Figure 37. Cutterhead-type dredge, YM-09, 1943 (Bureau of Aeronautics 1943).

Finally, record requests were filed separately with the USCG's Data Management & Administration Division, and Office of Information Resources (i.e., USCG Historian's Office) under the Freedom of Information Act. Both offices were unable to locate any information matching *Gulf Tide*'s description (Havern 2008; Martin 2008).

4.4.3 Previous Investigations

In 1997 Racal Inc. (1997) recorded an approximately 110-ft-long (33.5-m) by 75-ft-wide (22.9-m) wreck in the vicinity of the reported AWOIS location for *Gulf Tide* (Figure 38). In 2003, archaeologists investigated the site and determined that the loss of structural integrity was too great for the site to be NRHP eligible.

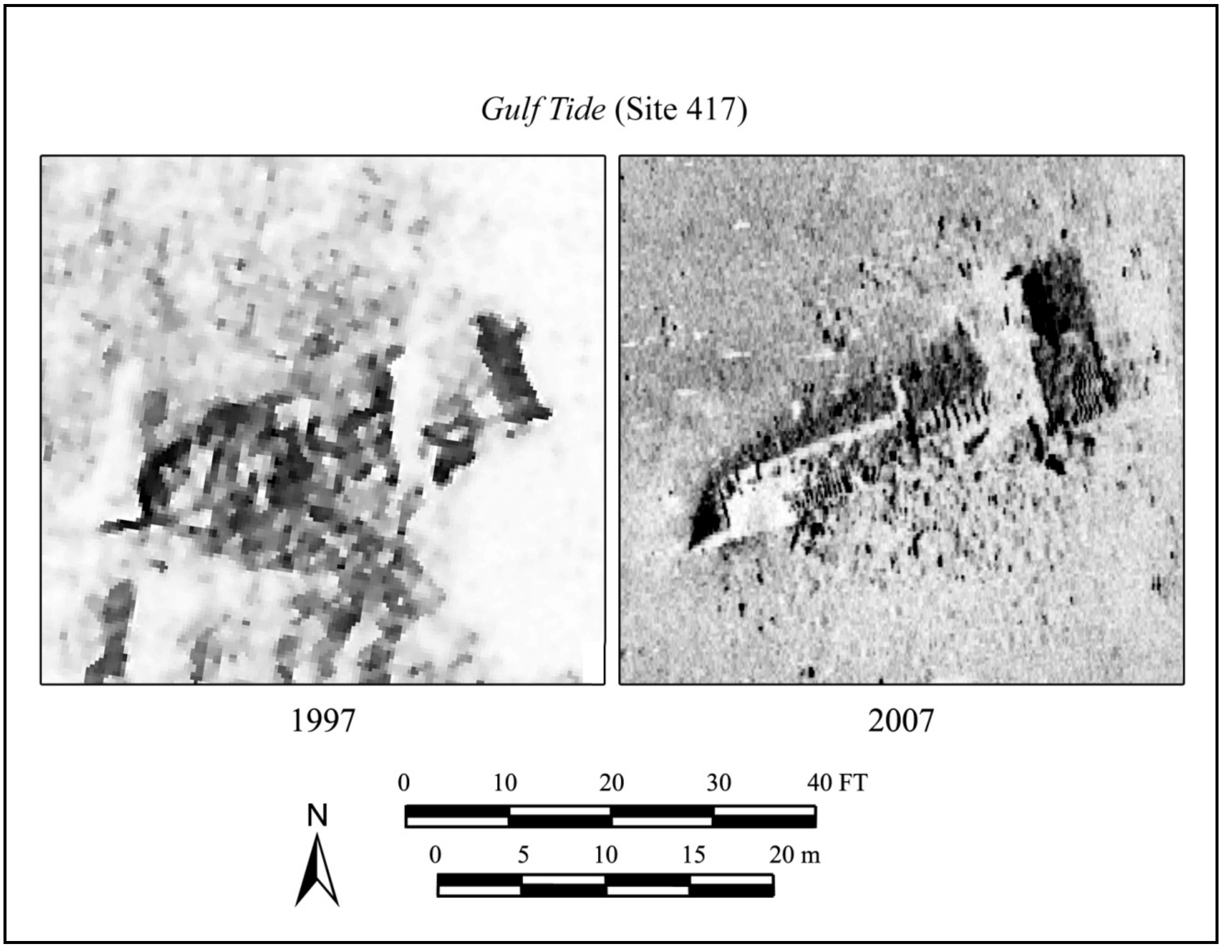


Figure 38. Pre- and posthurricane sonar imagery for *Gulf Tide* (1997 image courtesy of BOEMRE).

4.4.4 2007 Remote-Sensing Survey

Gulf Tide was resurveyed in May 2007. Side-scan sonar data showed a shipwreck approximately 100 ft (30 m) long and tapering from a maximum breadth of 30 ft (9.1 m) at its eastern end to 11 ft (3.4 m) at its western end (see Figure 38). The imagery showed two distinct sections of wreckage, separated by 10 ft (3.0 m). It was unclear from the data whether this represented two isolated wreck fragments or one section that was partially buried at its midsection. There appeared to be less wreck exposure relative to the 1997 sonar, but comparison of the two data sets was inconclusive because Racal Inc.'s survey was conducted at longer range and lower resolution. Based on interpretation of the available imagery, there were no clearly identifiable hurricane impacts at the site.

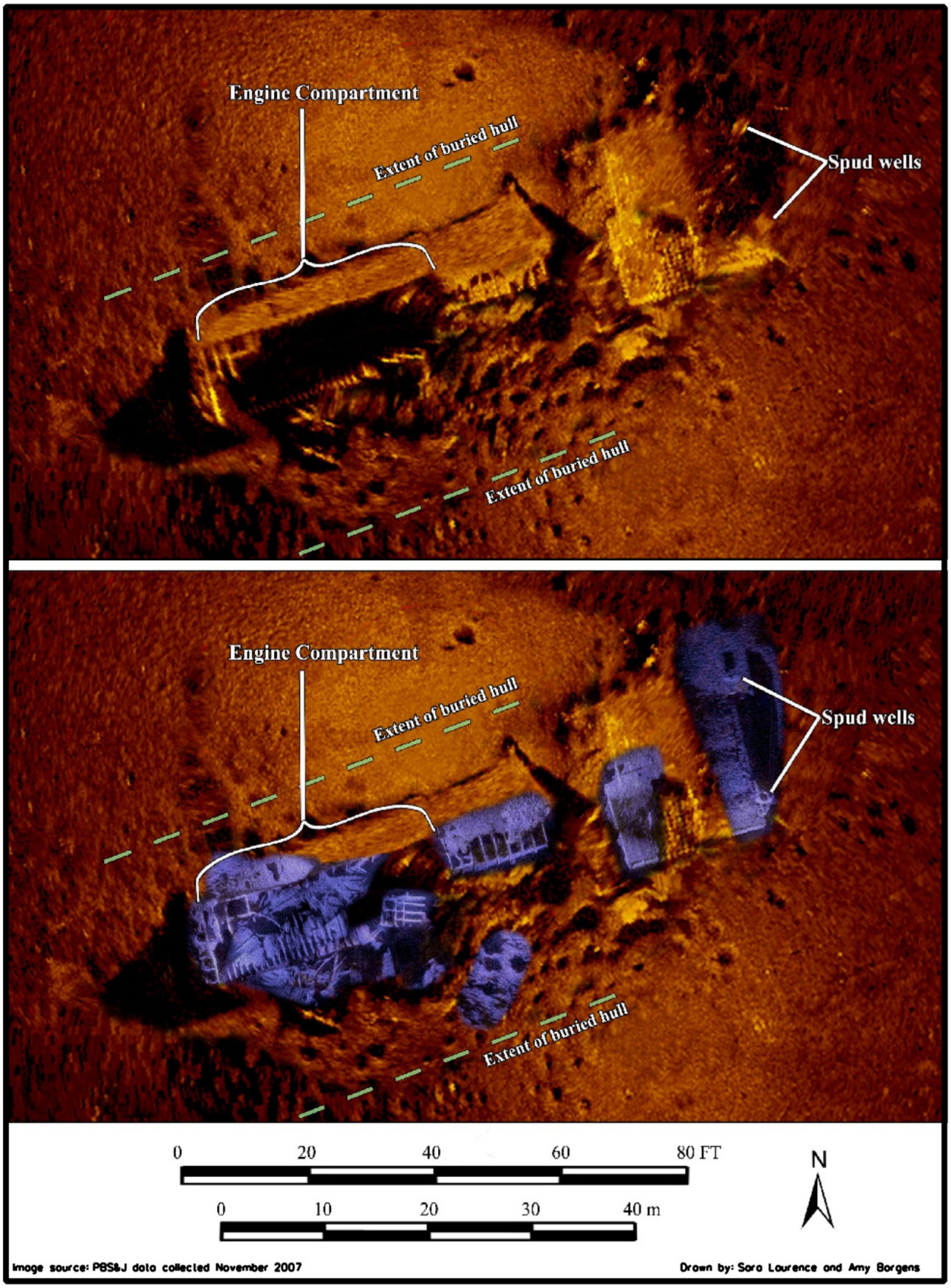


Figure 39. *Gulf Tide* Sector-Scan and DIDSON Data.

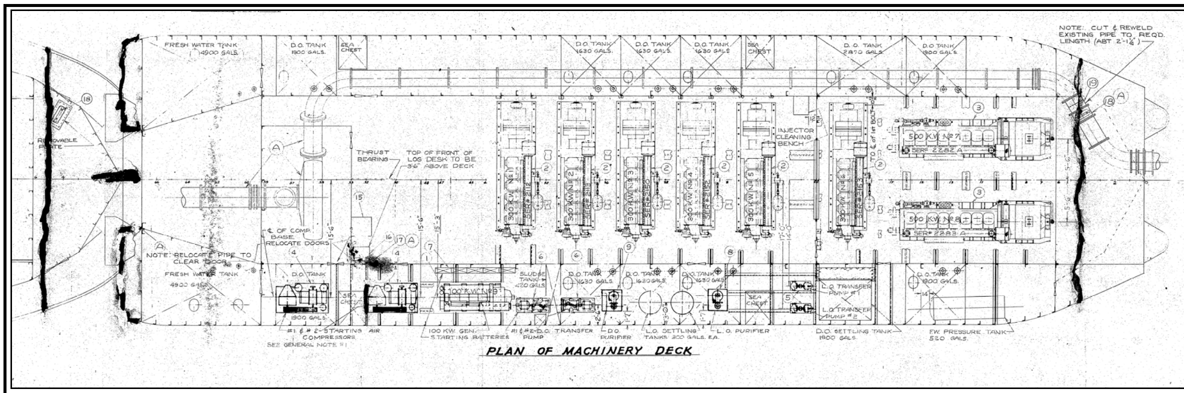
4.4.5 2007 Diving Investigations

Fifteen dives were conducted on-site over two days in October 2007. The depth range of exposed wreckage was between 48 and 53 ft (14.6–16.2 m). Because of the zero-visibility conditions, diver observations were supplemented by DIDSON and sector-scan sonar imagery. Two discrete hull sections were identified, separated from each other by between 4 and 15 ft (1.2–4.6 m) (Figure 39). The eastern section measured 25 ft (7.6 m) long by 32 ft (9.8 m) wide and was characterized primarily by a flat, featureless steel surface, exhibiting areas of extensive corrosion including a 7-x-9-ft (2.1-x-2.7-m) hole in the center of the hull. Attached to the far eastern edge of the hull were two spud gates with partial remnants of their respective spud wells (see Figure 39). In this same area, a bollard was also identified on the underside of the hull. Consequently, these features indicate that this hull section represents the overturned stern, and the orientation of the spud gates and wells further confirms that the vessel was a cutterhead-type dredge (USACE 1983:3–8).

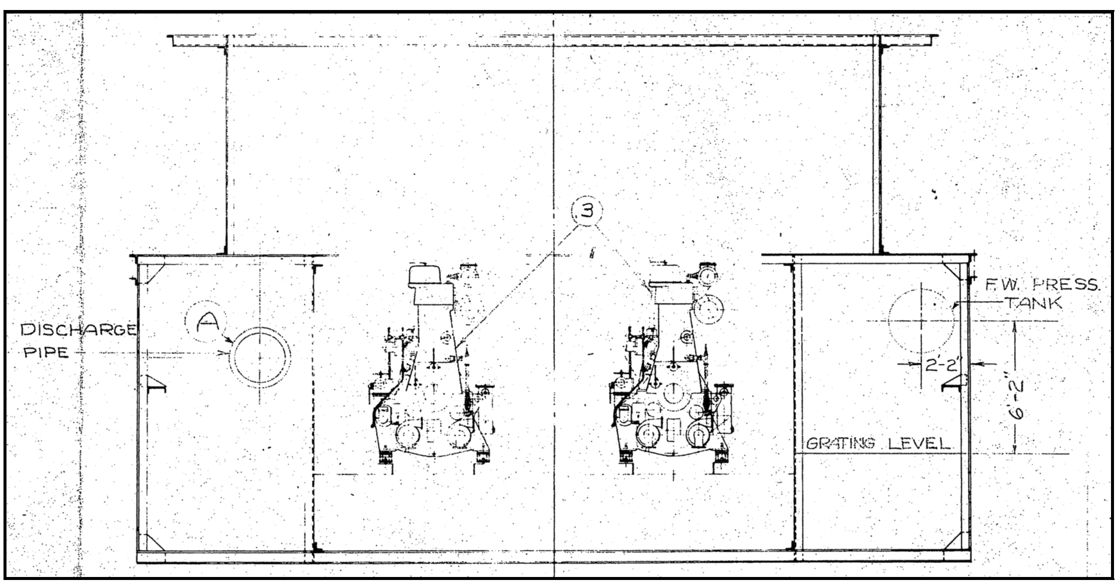
The exposed area of the western (forward) hull section measures 65 x 18 ft (19.8 x 5.5 m) based on the sonar data. Significant amounts of disarticulated metal and partially buried hull made construction details difficult to interpret in this area; however, several features indicate that this section is likely the starboard remnants of the machinery deck, oriented keel-down. The northern margin of the wreckage is characterized by a 4–13-ft-wide (1.2–4.0-m) flat surface of hull plating that extends the length of the exposed wreck and is buried in the sand along its northern edge. The southern (inboard) edge of the plating terminates at an approximately 4-ft-deep (1.2-m) vertical bulkhead containing vertical 4-inch (10.2-cm) molded beams spaced at 2-ft (0.6-m) centers. Moving both forward and aft, this bulkhead eventually intersects perpendicularly with two other vertical bulkheads effectively creating two — and a partial third — sides of a rectangular cavity around the forwardmost section of the wreck (see Figure 39). At the base of these bulkheads is a horizontal deck with a grating of beams spaced at 1-ft (0.3-m) centers. Overlaying this deck are numerous pieces of disarticulated metal, including pipes with internal wiring.

In order to determine the extent of buried site remains, probe transects were placed to the north and south of the forward hull section and also in the gap between that section and the stern. Probing revealed an additional 8 ft (2.4 m) of buried hull remains northward of the forward hull section (see Figure 39), equaling a total of 14 ft (4.3 m) from the bulkhead to the end of buried hull. Burial depths along probe transects gradually deepened from 2 inches (5.1 cm) adjacent to the exposed wreck to 2 ft 10 inches (0.96 m) at the outermost probe. On the southern side of the wreck, a single probe transect encountered an additional 20 ft (6.1 m) of buried material outside of the exposed remains. Sediment cover in this area was generally 2 inches (5.1 cm) thick. Factoring in the buried areas, total site width is at least 58 ft (17.7 m). A third probe transect was placed in the gap between the two sections of broken hull to determine whether the two fragments were completely separated or attached underneath the sediment. Using a 2-ft (0.6-m) probe and beginning at the forward end of the 10-ft (3.0-m) gap, no buried material was probed for the first 5 ft (1.5 m). Beginning at 6 ft (1.8 m) from the forward hull section, a downward-sloped extension of the exposed stern hull was probed at gradually shallower depths. It is possible that this feature continued to slope to a depth beyond the length of the probe, explaining why no material was encountered in the first 5 ft (1.5 m) of the probe transect.

Following the field documentation and subsequent research at the National Archives, PBS&J compared the site data with deck plan drawings of YM-22, a Navy dredge boat in operation around the same time as *Gulf Tide*. At 81 ft (24.7 m) long with a 20-ft (6.1-m) beam, YM-22 was of similar size to *Gulf Tide* and, therefore, may provide a useful template for *Gulf Tide*'s design features. Based on this comparison, the *Gulf Tide* wreckage appears to represent the starboard side of the machinery deck. The YM-22 plans show that dredge's diesel engines, generators, and pumps placed on an engine room floor, recessed below the main deck (Figure 40). There are bulkheads at either end of the engine floor space: one at the bow, where the main intake pipe and suction pump entered the engine room, and a second at the stern end of the engine compartment. This floor and bulkhead configuration closely resembles the layout observed on *Gulf Tide.* The distance between these bulkheads on YM-22 is 37 ft (11.3 m). Based on sonar data, the distance between the bulkheads on *Gulf Tide* is ca. 39 ft (11.9 m). The total engine space width of YM-22 is 11 ft (3.4 m), and the extant engine space on *Gulf Tide* is ca. 13 ft (4.0 m) wide. YM-22's machinery also sits on a grid of support beams spaced 2 ft (0.6 m) apart, while deck beams for the upper walkway of the machinery deck are spaced at 1 ft (0.3 m). This configuration is the exact opposite of *Gulf Tide*, where the engine room floor beams are 1 ft (0.3 m) apart and the vertical beams are 2 ft (0.6 m) apart.



(a) YM-22 plan of machinery deck



(b) YM-22 section at FR 18 looking aft

Figure 40. YM-22 plans (U.S. Bureau of Ships 1951a).

If this interpretation is correct, then clearly *Gulf Tide*'s machinery has been removed, possibly by salvage after its sinking. The numerous disarticulated remnants in this area of the wreck could be evidence of such salvage activity. There are also no visible remains of any superstructure. The engine house and pilothouse were likely constructed of wood, making it probable that they have been either destroyed by marine organisms or became dislodged and floated away during the period when the wrecked vessel was partially awash on the surface. If the wreck was salvaged at any point, the cutterhead, intake and outtake pipes, A-frame, and other mechanical elements were likely also salvaged. However, some of these features may also account for the buried wreck elements located during probing. If *Gulf Tide* broke apart, as was reported by the USCG (AWOIS Record 362), there may be significant vessel remains underneath the two extant hull fragments.

4.4.6 Sedimentology

Two box cores were collected at *Gulf Tide* (Figure 41), one along an east-west orientation (parallel to storm wave propagation) and one along a north-south orientation (perpendicular to wave propagation). The cores were further separated into a total of eight subsamples based on stratigraphy (three for the north-south core and five for the east-west core). Particle-size results are presented in Table 13.

Figure 41. Box cores collected at *Gulf Tide*.

Table 13

Gulf Tide Particle-size Results

Sample	Provenience	% Gravel	% Sand	% Silt	% Clay	Mean phi	Classification
1-*Gulf Tide*	N-S 0-7 cm bml	9	51.5	27	5.5	4.12	Coarse silt
2-*Gulf Tide*	N-S 7-10 cm bml	12.5	66.5	11.5	2	3.26	Very fine sand
3-*Gulf Tide*	N-S 10-29 cm bml	3	77	10	3	3.38	Very fine sand
4-*Gulf Tide*	E-W mixed levels	6	75.5	12.5	2.5	3.35	Very fine sand
5-*Gulf Tide*	E-W 0-4 cm bml	2.2	51.5	38	1.5	4.15	Medium silt
6-*Gulf Tide*	E-W 4-5 cm bml	3.5	86.5	0	8	2.82	Fine sand
7-*Gulf Tide*	E-W 5-21 cm bml	6.5	79	11.5	0	3.26	Very fine sand
8-*Gulf Tide*	E-W 22.5-29 cm bml	13.5	68	14.5	2.5	3.16	Very fine sand

On the north-south axis, there is mud from 0 to 7 cm (0 to 2.8 inches) and two zones of very fine sand from 7 to 10 (2.8 to 3.9 inches) and 10 to 29 cm (3.9 to 11.4 inches). The results were similar on the east-west axis. Mud was present from 0 to 4 cm (0 to 1.6 inches), underlain by a lens of fine sand from 4 to 5 cm (1.6 to 2.0 inches), and two zones of very fine sand from 5 to 21 cm (2.0 to 8.3 inches) and 22.5 to 29 cm (8.9 to 11.4 inches). The lens of fine sand was not apparent on the north-south axis. This predominance of fine and very fine sand near the surface is likely a contributing factor in the increased burial of the site since the 1997 survey. These small particulates would be easily reconfigured when energized by hurricane-induced currents, resulting in the diver-observed burial of lower-profile wreck features outside of *Gulf Tide*'s visible hull. The data indicate that *Gulf Tide* may be vulnerable to increased subsidence in these fine sediments over time. Based on probing, however, wreck features are known to be present at least 2 ft 10 inches (0.86 m) below the mudline, which is below the coring depth. Without deeper coring data, characterization of the soils at the sediment/wreck interface cannot be quantified.

Other sources indicate the site may rest on relatively cohesionless sandy sediments 3.3 to 4.9 ft (1 to 1.5 m) thick, based on data recorded in an adjacent block (Berryhill 1984:Sheet VI). PBS&J sonar imagery suggests the presence of small localized pockets of finer material occurring in the vicinity and a linear transition to coarser material located west and northwest of the site (Figure 42). This linear transition might indicate the presence of a buried fault, as Berryhill and Owen (1984:Sheet III) map three faults nearby, all buried at least 16.4 ft (5.0 m). These faults might be associated with anticlinal folds mapped by Berryhill and Owen in blocks to the northwest and southeast and a diapir located in the next block south.

According to maps produced by McClelland Engineers (1979:Plate 2A), Pleistocene soils formed under subaerial conditions during the Late Wisconsin glacial period are less than 20 ft (6.1 m) beneath the modern mudline in the vicinity of *Gulf Tide*. Berryhill et al. (1984:Sheet II) did not map buried stream channels in the same lease block, although channels from the Late Wisconsin Glacial Epoch mapped in adjacent blocks trend in directions suggesting they would connect across the center of *Gulf Tide*'s lease block location.

Figure 42. Surface sediments in the vicinity of Gulf Tide.

McClelland Engineers (1979:Plates 3A, 4A, 5A) mapped the shear strength soils at the seabed in the vicinity of *Gulf Tide* in the range of 0.6 to 0.8 ksf, which they qualitatively described as firm. The shear strength was mapped as 1.0 to 1.5 ksf (stiff) at a depth of 10 ft (3.0 m) below the seafloor and as 1.0 ksf (firm-stiff) at a depth of 20 ft (6.1 m). The OTRC (2004) map constructed using method 1 (see description in *Castine* sedimentology results, Section 4.2.6) shows soil shear strengths surrounding the location of *Gulf Tide* as 2.3 ksf (very stiff) at the mudline, 2.2 ksf (very stiff) at 5 ft (1.5 m) below the seafloor, and 0.5 ksf (soft) at 10 ft (3.0 m) below the seafloor. These maps indicate that *Gulf Tide*'s probability for increased subsidence is low; however, according to OTRC data, *Gulf Tide* is located within a sand polygon from the mudline to 10 ft (3.0 m) below the seafloor, which contradicts their maps produced using method 1. It also means that their shear strength map constructed using method 2 did not calculate shear strengths in the area of *Gulf Tide*. OTRC's data on sand content match PBS&J's box core data for the top 1 ft (0.30 m) of the site. This indicates that increased subsidence of *Gulf Tide* from Hurricane Rita or future natural events is possible, though inconclusive without collecting deeper coring samples and/or shear strength measurements at the site.

Finally, on both sector-scan and DIDSON imagery, small craters were observed in the sand within the radius of buried wreckage, but not in the surrounding seabed (see Figure 39). These craters are indicative of air or some other gas that had been trapped under the wreck but then "bubbled" to the surface at some point. This process could have been catalyzed by differential pressures resulting from storm waves passing over the wreck.

4.4.7 Impact Assessment

Hurricane Rita passed 8.4 mi (13.5 km) east of *Gulf Tide* as a Category 3 storm at 12:30 A.M. on September 24, 2005. This was the closest approach of either Katrina or Rita to one of the study wrecks. Peak sustained winds over *Gulf Tide* were estimated by Oceanweather, Inc.'s (2006) hindcast model at 79 mph (35.5 m/s) from a direction of 219 degrees. The maximum significant wave height over *Gulf Tide* was estimated at 22.6 ft (6.9 m) from a direction of 112 degrees. At peak storm conditions over the site, maximum bottom currents of 6.5 mph (2.9 m/s) struck *Gulf Tide* along its port side from the stern at an angle of 43 degrees relative to the ship's orientation. At intervals of 7.75 seconds, the current reversed direction 180 degrees beneath the wave troughs to a velocity of –2.0 mph (–0.9 m/s), then peaked again 7.75 seconds later at 6.5 mph (2.9 m/s) in the forward direction beneath the next wave crest. The amplitude of velocity change from forward to reverse, on an interval of 7.75 seconds, was 8.5 mph (3.8 m/s). Given the difference in density between seawater and air, the damage potential represented by the maximum forward water velocity is equivalent to that of a 183-mph (81.8-m/s) wind or analogous to an F4 tornado. *Gulf Tide* experienced the second strongest bottom currents of the four primary study wrecks. This site is the shallowest of the study wrecks, so the potential exists for extreme bottom currents from any close hurricane passage.

There has clearly been a high degree of degradation to this site since its sinking in 1947. In several areas, outer hull plating has deteriorated to reveal internal framing, and the orientation of the fragmented hull sections indicates that the site has been exposed over time to fairly dynamic forces. There are no impacts that can conclusively be associated with Hurricane Rita, however. The only quantifiable difference between the pre- and poststorm condition of the wreck is the width of exposed remains. The 1997 Racal Inc. survey recorded a site that was approximately 75 ft (22.9 m) wide, while PBS&J's data show only approximately 30 ft (9.1 m) of exposed wreckage, with at least an additional 28 ft (8.5 m) of buried remains. Even this comparison is problematic because of the low-resolution imagery collected by Racal Inc. The increased burial may be the result of natural sediment transport processes in this area of the GOM, or it may be due to sediment transport associated with localized hurricane activity. If 75 ft (22.9 m) of wreckage were still exposed after 50 years of site creation, it seems probable that burial of more than half the site in the 10 years between surveys was induced by an acute change in local environmental conditions (i.e., passage of a hurricane). This is particularly probable when considering the proximity of *Gulf Tide* to Hurricane Rita's path. The presence of small craters in the surrounding sediment is evidence that trapped gases, presumably air, have been released from the site since Rita. It seems likely that pockets of air accumulated beneath wreckage during Rita, then continued releasing to the surface following passage of the storm, thus preserving the small craters over the site. A similar pattern was observed in posthurricane imagery of *Josephine*, located 46 mi (74.1 km) west of Katrina's path (see Appendix A).

Apart from changes in the sediment cover, there is little in the structural condition of the wreck that can be conclusively associated with hurricane impacts. *Gulf Tide* was reported to have broken apart while still partially afloat, which could account for the separated and overturned stern section. Furthermore, if the site was salvaged, which seems likely considering the lack of remaining machinery, this activity could have accelerated the rate of material decay long before passage of Hurricane Rita. Without better knowledge of the prestorm conditions of the site, any determinations of poststorm impacts remain inconclusive.

The closest petroleum-industry damage reported near *Gulf Tide* was a Mariner Energy, Inc. pipeline that was pulled up 7.5 mi (12.0 km) northeast of *Gulf Tide*'s position, almost directly in Rita's path. Several other pipelines, including one only 1.6 mi (2.6 km) north of *Gulf Tide*, had no reported damage. This implies that storm-induced bottom disturbances in the vicinity of *Gulf Tide* were relatively less severe than in surrounding areas.

4.4.8 National Register Assessment

A 2003 diver reconnaissance of *Gulf Tide* previously determined the site to be too heavily disturbed to qualify for NRHP eligibility. Based on the 2007 investigation of the site, however, PBS&J believes *Gulf Tide*'s eligibility status is still an open question. Too little is known of *Gulf Tide*'s construction and use history to determine its potential historical significance. Depending on its construction date, it may represent an early example of diesel-powered cutterhead dredges, a vessel type that has been the most widely used in the United States, particularly for pipeline installations and navigation channel creation and maintenance projects. This type of vessel has been described as an "American specialty" that has been more highly developed and widely used for submarine excavation than in any other part of the world (Herbich 2000:4.17). Furthermore, significant amounts of the vessel hull and upper deck mechanical elements may still be present, buried in situ under the exposed hull fragments. Until further information can be obtained on *Gulf Tide*'s history and the types of material that may still be present on-site, PBS&J recommends that *Gulf Tide*'s NRHP status remain inconclusive.

4.5 *New York*

The steamship *New York* (BOEMRE vessel ID 344; Figure 43) is located in the High Island lease block area, 34.4 mi (55.4 km) northwest of Hurricane Rita's path. The strongest winds estimated over the site during Rita's passage were 69 mph (30.8 m/s). Peak significant wave height over the site was estimated from hindcast data at 18 ft (5.5 m).

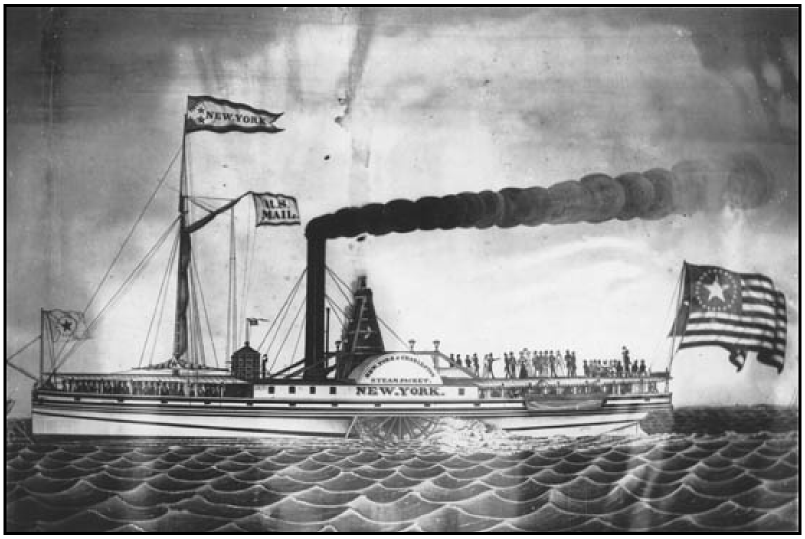


Figure 43. SS *New York* (courtesy of the Mariners' Museum, Eldredge Collection).

The wreck was first discovered in 1990 following a five-year search by a group of amateur wreck salvers named *Gentlemen of Fortune*. In 1997, *Gentlemen of Fortune* voluntarily brought the wreck to the attention of BOEMRE archaeologists. In 2006, *Gentlemen of Fortune* filed a civil action in U.S. District Court for salvage rights to the site. The court ruled in the group's favor in January 2007 (U.S. District Court, Western District of Louisiana, Lafayette-Opelousas Division 2007).

4.5.1 History

The SS *New York* was a Charles Morgan steamship that ran between New Orleans and Galveston beginning in 1839. The side-wheeler was built in 1837 by William H. Brown, a well-established shipbuilder of New York City. William H. Brown operated one of two shipyards (the other being Bishop and Simonson) that were opened at New York City in 1834 and that were widely known for their steam vessels (Morrison 1909:59). The low-pressure crosshead steam engine was manufactured at Allaire Works, the first of the large marine engine works in New York City (Morrison 1909:38). Its registered dimensions were 160 ft 6 inches x 22 ft 6 inches x 10 ft 6 inches (48.9 x 6.9 x 3.2 m), with a burden of 365 tons (Works Progress Administration 1942:207).

New York was originally a packet/passenger steamer for the troubled New York and Charleston Steam Packet Company, operated by John Aymar, Benjamin Aymar, James P. Allaire, John Haggerty, and Charles Morgan. It was one of two steamers, along with *Home*, built after reorganization of the company in 1836 following the departure of Benjamin Aymar (Baughman 1968:16–17). The construction of *New York* and *Home* was finished in 1837, and the steamers joined *Columbia* on the Charleston run in early 1837. In October 1837, on her third voyage, the lavishly built *Home* grounded and swamped during foul weather off Cape Hatteras killing 99 passengers and crew, including one of Allaire's relatives (Baughman 1968:7–18; *Courier* 1837). After this tragic and expensive loss, the company was again reorganized, and *New York* was paired with *Neptune* on the Charleston route.

James Allaire was stung by the public outcry and desire to assign blame for the loss of *Home,* and he withdrew from the company to focus on Allaire Works, leaving Morgan as the managing partner of both *Columbia* and *New York* (Baughman 1968:18–19). In the wake of the disaster, Morgan refocused his entrepreneurial energies on shifting the steam line to New Orleans. Morgan's proliferation into Texas commenced an ambitious marine and rail line into the territory and by midcentury lead to the creation of the major port and Morgan Line hub at Indianola (Baughman 1968; Malsh 1978). *Columbia* arrived at New Orleans on November 18, 1837, initiating Morgan's steam service in the GOM (Baughman 1968:21). The introduction of Morgan's service to the GOM greatly stimulated economic diversity and growth in the region, especially at Galveston, which initially did not even have a suitable wharf to receive the vessel and its cargo (Baughman 1968:23; *New York Times* 1878:4). *Columbia*, considered "one of the best and safest boats in the United States," was joined by *Cuba* in June 1838 and *New York* in January 1839 (Baughman 1968:24, 26*; Civilian and Gazette* 1838). *New York* was characterized as exceeding *Columbia* in elegance (Baughman 1968:26).

An early advertisement for *New York* was printed in *The Civilian and Gazette* (Galveston) on January 11, 1838. According to the paper, it was to arrive in port at the end of November as a regular packet between New Orleans and Galveston. It boasted accommodations for 200 passengers, the ability to carry 600 barrels freight and conduct passage in 30 hours. The agents for the vessel were McKinney and Williams, the largest, and most-well-known mercantile house in the Republic of Texas. The vessel was luxurious and commodious, advertising 180 ft (54.9 m) on deck, 22 ft (6.7 m) breadth, and an 11-ft (3.4-m) hold. To further promote the new steamer, McKinney and Williams displayed a drawing of the vessel in their "counting" room in Galveston (*Civilian and Gazette* 1838). Despite its predicted November appearance, it was first advertised in the New Orleans paper in January 1839 for a departure date of February 1st (*New Orleans Bee* 1839a). The agents at New Orleans were Bogert and Hawthorn (*New Orleans Bee* 1839a). The steam packet cleared the port of New Orleans for Galveston on February 2, 1839 (*New Orleans Bee* 1839b).

The steam packet *New York* was well marketed. Advertisements of the period boasted a "highly finished and fast running boat" and "a most beautiful boat" (*Civilian and Gazette* 1838). In 1839 the steamer was slightly over a year old and had just begun operating on the New Orleans to Galveston route (Baughman 1968:26). The opulence of the vessel was described in a letter written by Mary Austin Holley, a well-known chronicler (and inadvertent propagandist) of Texas, in 1840:

> The cabin of the New York is on the upper deck like the river boats, the whole of it mahogany & maple polished like the finest piano – drapery (where there is any) of blue satin damask, & dimity. The windows of painted glass representing the Texas arms. The table china is white, with a blue device in the center of each plate representing the New York at sea with the Texas eagle hovering over her. Every article was made express for the boat – ivory knives, polished to the highest degree, & the silver forks & spoons (not German silver) have Steam boat N. York engraved on them . . . . The boat is built for strength. They call it the finest work that ever came out of New York. (Holley 1933)

In 1843, *New York* was reported as having been overhauled while "up north" with new wrought iron shafts (*Civilian and Gazette* 1843). It also received a new certificate of registry at New Orleans on March 10, 1843, under the ownership of John. D. Phillips, Charles Morgan, and John Haggerty. By 1845, the vessel had received more maintenance and was again thoroughly overhauled with new copper boilers. Part-owner John D. Phillips was now also *New York*'s captain. Former Captain John T. Wright was transferred to master of Morgan's new 548-ton side-wheel steamer *Galveston* (Baughman

1968:39; *Civilian and Gazette* 1845). Wright was a career captain for Morgan and was usually promoted to the newest of Morgan's boats upon their acquisition. Prior to his tenure on *New York*, Wright was master of *Columbia* in 1837, considered the first vessel of the Morgan Line (Baughman 1968: 24).

As a steam packet, *New York* could carry freight and accommodate passengers in their luxurious staterooms, cabins, steerage quarters, or on deck. In 1843, staterooms were priced at $25.00, cabins at $20.00, steerage $12.00, and deck seating was $8.00; amounts comparable to between $748.00 and $239.00 in present-day dollars (*Civilian and Gazette* 1843; Officer and Williamson 2009). Steerage was below deck with sleeping berths partitioned by curtains. Steerage passengers had access to the awning-covered decks though they had to "find" and prepare their own meals. These accommodations were viewed as more comfortable than that of the deck passengers (Baughman 1968:12).

On September 7, 1846, while en route to New Orleans, the vessel broke apart and sank during a hurricane off the Texas coast near Galveston. Detailed accounts from survivors attest to prolonged and harrowing attempts to save the steamer during a violent, unforgiving hurricane. *New York* initially encountered the storm at 10 PM on the evening of September 5 wherein the vessel anchored, then later continued on her course. Shortly after recommencing her journey, the vessel again anchored with the intention of riding out the storm. On the afternoon of September 6, the steamer struggled to keep its position until a change in wind direction, from the north and east to southeast, foreshadowed the subsequent events. Gale force winds pushed *New York* into the trough where she was battered by waves that removed the port and starboard guard, smoke pipe, wheelhouse, pilothouse, and portions of the decking, lifted the promenade, and caused tremendous leakage, which extinguished the boiler fires. After laboring against the storm for 56 hours, *New York* ultimately broke apart and sank in the early morning on September 7. Nearly half of the passengers and crew perished, and between $30,000 and $40,000 in gold, silver, and bank notes was lost with the ship (*Civilian and Gazette* 1846; *Daily Picayune* 1846; *New Orleans Bee* 1846:1).

At the time of its sinking, *New York* carried 30 passengers and 24 crew. Twelve passengers perished in the tragedy, though all but seven of the crew were spared, including Captain Phillips. Incidentally, a larger proportion of women and children died than men; seven of the 12 passenger deaths were woman and children. The only surviving females onboard the vessel were a Mrs. Follett, whose three children perished, and a chambermaid named Sarah (*New Orleans Bee* 1846:1; Table 14). Coincidentally, a Miss Follett was also identified as one of the deceased passengers, but any relation to Mrs. Follett and her children is unknown.

The survivors of *New York* were rescued by the crew of Morgan's new steamer *Galveston*, which was on the same route from Galveston to New Orleans. *Galveston* towed one of its boats alongside to help retrieve survivors, some of whom had drifted several miles from the wreck location (*Manchester Examiner* 1846). As captain of *Galveston*, John T. Wright was responsible for the rescue of passengers and crew from the vessel for which he had recently been master. Both *New York* and *Galveston* were chartered to the U.S. government to transport supplies to U.S. troops stationed in Texas during the Mexican-American War. After the loss of the uninsured *New York,* Morgan's military contracts diminished, as *Galveston* had to absorb U.S. mail and civilian and business transportation formerly allocated to *New York* (Baughman 1968:45; *New York Times* 1878:4).

Table 14

Lists of Passengers and Crew of *New York*

Passengers Saved	Passengers Deceased
Judge Toler (Dan Toler)	Mrs. Wilson
Mrs. Follett	2 unnamed Wilson children
T.W. House	Miss Follett
Mr. McCormick (A. McCormick)	A. H. McCormick
Mr. Stakes (A.G. Stakes)	3 unnamed Follett children
Mr. Papard (J.G. Peppard)	Wm. Armstrong
Dr. Banzano (M.F. Bonzano)	one cabin passenger, name unknown
Capt. Tod (John Y. Tod)	two deck passengers, names unknown
Mr. Smithers (G. Smither)	
J.W. White (John W. White)	
Cuhn (Ludwig Cuhn)	
Gorman (Oliver Gorman)	
G.W. Goolley	
McCafferty (J.M. Cafferty)	
Sheppard (James W. Sheperd)	
W. J. Hutchins	
Hefferman	
Clermont	
Crew Saved	**Crew Deceased**
John D. Phillips, captain	James Wilson, 2nd steward
Dan Phillips, clerk	Pheneas Marsh, 2nd engineer
Wm E. Haviland, 2nd mate	Charles Wilson, seaman
Geo. Miner, engineer	John Groghan
Edward Conrey, 2nd engineer	Wm. McRea, fireman
John Conrey, cook	2 seaman, names unknown
Michael Murphy, seaman	
Peter L. Lesea, seaman	
Wm. Rice, fireman	
Wm. Johnston, fireman	
Geo. Sainways, fireman	
Edward Murphy Palmer, fireman	
Wm. Larkin Palmer, carpenter	
Peter Moran	
Sarah, chambermaid	

From the *New Orleans Bee* (1846). Alternate spellings from other source material are included in parentheses.

As might be expected on a vessel of its class, many of the survivors were affluent businessmen, including Judge Daniel Toler, T.W. House, and J.W. White. Daniel J. Toler, the former Postmaster General of Texas, was on a return trip from Washington with complete instructions for Morgan's New Orleans-Galveston Service. Toler 'barely' survived the accident though the official paperwork was lost (Baughman 1968:40). Thomas W. House was originally the owner of a bakery and confectionary establishment in Houston. His business developed from candy and confectionary to more-general merchandise and dry goods, known as the firm of T.W. House & Company. His later purchase of James H. Stevens and Co. in 1853 created the largest wholesale and grocery business in the state (Lewis Publishing Co., 1895:314). John W. White, a Houston native, was part owner of the Houston mercantile business White, Pool, and Company. In the mid-nineteenth century, White established himself in the hotel business as proprietor of the "White House" until his death in 1859 (Lewis Publishing Co., 1895:466). Another survivor of the tragedy was Col. William J. Hutchins. Hutchins was a successful businessman who operated various mercantile ventures in the Houston area beginning in the late 1830s. By 1860 he was known throughout Texas and other northern markets as having "an enviable reputation for business integrity and fair dealing." After selling his mercantile interests in 1861, Hutchins became one of the original shareholders of the Houston & Texas Central Railroad (Lewis Publishing Company 1895:276).

Max F. Bonzano, another surviving passenger and German immigrant, studied medicine in New Orleans in 1843. He had anticipated completing his studies in 1845, relocating to Texas, and practicing as a doctor for the San Saba Colonization Company (Biesele 1930). Bonzano was instead elected as a visiting physician at Charity Hospital until 1848 when he was appointed by President James Polk as melter and refiner of the New Orleans mint. Following the Civil War, Dr. Bonzano was appointed chairman of the Committee on Emancipation and, as such, wrote the ordinance of emancipation for Louisiana, which won by majority. Bonzano later served as supervisor of internal revenue, surveyor-general, and, in 1874, superintendent of the mint (Goodspeed Publishing Company 1892:303–306).

One of the most well-established naval officers in the state, Captain John G. Tod was a midshipman in the United States Navy until his medical discharge in 1836. Tod was appointed naval inspector for the Texas Navy in 1838 and later became one of the navy's purchasing agents in Boston. Tod largely orchestrated the construction and outfitting of the vessels that comprised Texas's second navy in 1839. In 1840 Tod was promoted to secretary of the (Texas) navy, an appointment he later resigned. He briefly left Texas and traveled to Washington to lobby for the annexation of Texas. In 1845 he returned with the official notification of annexation. During the Mexican-American war, Tod served in the United States Navy and as an agent of the United States quartermaster general at the Brazos Santiago Depot and at New Orleans. As a co-founder of the Buffalo Bayou, Brazos and Colorado Railway in 1852, Tod was also instrumental in bringing rail service to parts of Texas (Jordan 2006).

4.5.2 Archival Research

4.5.2.1 Mariners' Museum

The Mariners' Museum houses several sources that document various details of *New York*'s construction, use history, and/or wrecking event, though for the most part this information is redundant and widely available in other sources. The Eldridge Manuscript Collection contains a file of newspaper clippings and miscellaneous notes on *New York*. Eldridge was a steamship aficionado who compiled files of miscellaneous information on numerous nineteenth- and twentieth-century steamships, including dimensions, builder, historical information, newspaper clippings, images, and references to other pertinent sources. All files are arranged alphabetically by vessel name. In *New York*'s file, Eldridge notes that the steamer was built by Brown & Bell, that its engine was built by Allaire Works, and that the vessel was sold to John D. Phillips in January 1846. Three newspaper articles in the file reference mail deliveries made by the packet steamer to Galveston and New Orleans in 1839 and 1841, but provide no other details on the vessel. The Eldridge Collection also contains a copy of a painting of *New York* (see Figure 43), that is one of the only known images of the ship and has been previously published (Irion and Ball 2001).

There is also an entry for *New York* in *Early American Steamers* (Heyl 1953). Information includes the builder, dimensions, engine type (listed as "square"), owners, a historical sketch detailing the ship's use on the Southern Steam Packet Co. and Charles Morgan's New Orleans steamship line, and its eventual sale to John D. Phillips. There is also a profile-view sketch of *New York*, drawn by the author, showing details similar to those on the Figure 43 painting.

An article from the *New York Herald* (1846a) provides an account of the sinking as told to press in New Orleans by Captain Wright of *Galveston*. Included is a chronology of the worsening weather conditions and eventual wrecking event and a list of all passengers and crew, categorized as either "Saved" or "Lost and Missing." A second article from the *New York Herald* (1846b) briefly describes the extent of flooding and damage incurred at Galveston during the same storm that sank *New York.*

John H. Morrison's *History of American Steam Navigation* (1903) discusses the development of steam ships and commercial steamer lines, including those of Charles Morgan and his business associates. Some minimal details are provided on *New York*'s construction and early commercial career, along with brief sections on the New York to Charleston and New Orleans packet steamer lines, but there is little of relevance to the present study.

Finally, John L. Lochhead's *Disasters to American Vessels, Sail and Steam, 1841–1846* (1954) compiles a short list of entries in the *New York Shipping and Commercial List* between 1842–1846 when *New York* grounded or had mechanical difficulties of some kind. The September 19, 1846, entry describing the vessel's sinking reads:

> Steam ship NEW YORK, Phillips, from Galveston 5th inst. for New Orleans, was wrecked in a heavy gale 7th inst. and went down in 10 fathoms [60 ft (18.3 m)] water, where she had anchored having previously shipped heavy seas which caused her to leak badly, put out her fires, carried away smoke pipe, &c. Twelve passengers and five of her crew were drowned; the remainder including Capt. P. picked up and carried to New Orleans.

4.5.2.2 National Archives

While Forrest Holdcamper was researching NARA materials for *Merchant Steam Vessels of the United States 1790–1868* (Lytle and Holdcamper 1975), he maintained a card file of his findings (RG41). The note card for *New York* lists the number, date, and port of *New York*'s various registers and enrollments. Using this card as a finding aid, the first and last of *New York*'s enrollments were located. The original enrollment (No. 24, June 14, 1837, New York) was burned around the edges but was still mostly readable, and a copy was obtained. The final enrollment (No. 14, March 16, 1846, Galveston), which by convention should have included details of the steamer's sinking, was highly faded and unreadable.

Another note in Holdcamper's card file mentions a reference to *New York*'s sinking in "Sailor's Magazine, Vol. 19." The full title for this magazine is actually *The Sailor's Magazine and Seaman's Friend*, and it was a monthly publication of the proceedings of the American Seaman's Friend Society. The referenced Volume 19 was located at the Library of Congress, but the relevant entry on *New York* was simply a brief mention of the date, location, and details of the sinking, within a larger list of reported vessel losses.

4.5.2.3 New York Historical Society

Finally, PBS&J contacted the New York Historical Society's Manuscripts Collection to inquire about any materials the society may have pertaining to *New York*. After an extensive search of the collection finding aids, no relevant materials were located by the Society's staff (Kiter 2008).

4.5.3 Previous Investigations

Gentlemen of Fortune began their search for *New York* after reading a newspaper article that reported the loss of "thirty to forty thousand dollars in gold, silver, and bank notes" on the wreck (*Daily Picayune* 1846). Intrigued by this information, the group conferred with their contacts in the commercial fishing industry and began a systematic investigation of known net hangs in the GOM. One of these locations was tentatively determined to be *New York.* After the site was located, a salvage company was contracted to uncover the ship's buried hull. As a result, several artifacts were recovered that helped establish a date range for the wreck, including a mortising machine patented in 1836, an 1827 British gold sovereign, and two 1843 U.S. half dollars (Irion and Ball 2001).

In July 1997, a magnetometer and sonar survey of the site was conducted in order to determine the approximate site boundaries (Irion and Anuskiewicz 1999). At this time, the majority of the hull had been naturally reburied, leaving as the most prominent site features the steam engine (centered on the hull [Figure 44]) and a paddlewheel east of the main wreckage. A circular depression surrounding the wreck denoted the repeated prop-wash excavations (i.e., removing sediment overburden with a deflected and focused boat propeller stream) that *Gentlemen of Fortune* had undertaken on the site since 1994.

Also in 1997, a brief diver reconnaissance of the site was conducted in order to further investigate the low-pressure, cross-head steam engine. According to Irion and Ball (2001), "identifiable parts of the machinery included the steam chest, the cam, the air pump, and condenser. The main piston cylinder had broken free from the condenser and was partly buried in the sand." These engine parts corresponded to the crosshead-type engine known to exist on *New York,* and BOEMRE archaeologists concurred with the assessment of the wreck's identity, further concluding that the site was eligible for inclusion in the NRHP.

In 2001, Fugro Geoservices, Inc., conducted an archaeological and shallow-hazard survey of the High Island lease block area for Cronus Offshore, Inc. (Fugro Geoservices 2001). Fugro recorded 35 magnetic anomalies within their survey area, including a target at the unpublicized location of *New York*. Surveying at a 656-ft (200-m) transect interval with a 492-ft (150-m) side-scan sonar range, Fugro was unable to record an identifiable sonar target associated with this anomaly, and the site was misidentified as modern debris.

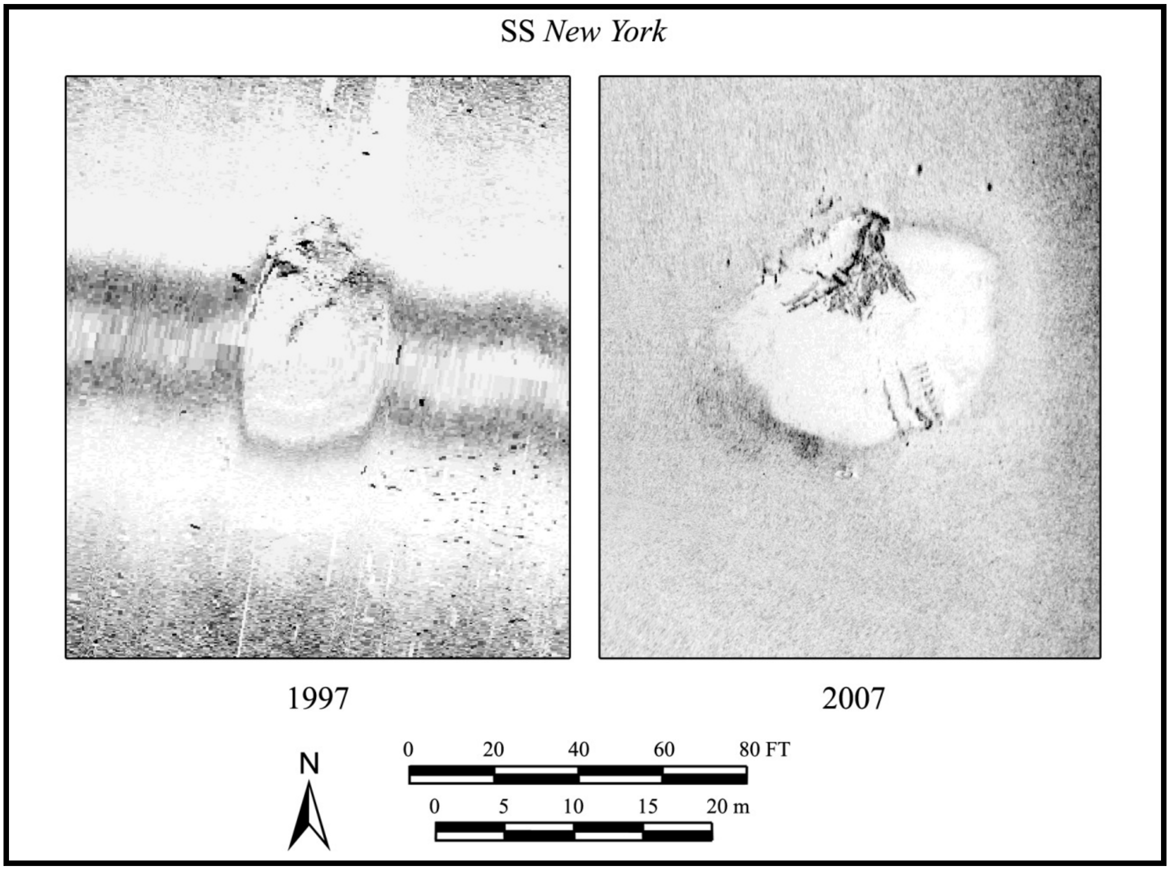


Figure 44. Pre- and posthurricane sonar imagery of *New York*.

4.5.4 2007 Remote-Sensing Survey

PBS&J conducted a magnetometer and sonar survey of the site on May 11, 2007. The resulting data were similar to the 1997 imagery, but with evidence of increased wreck exposure (see Figure 44). Portions of the crosshead steam engine were still evident, including the cylinder, steam chest, air pump, cranks, and the starboard paddlewheel shaft. The radius of prop-wash excavation had widened to 28 ft (8.5 m) (from about 22 ft [6.7 m] in 1997) and had been further deepened to reveal a 27-ft (8.2-m) section of framing forward of the engine compartment. Total site area had increased from approximately 1,500 ft^2 to 2,400 ft^2 (139–223 m^2). There was no obvious damage to the wreck beyond increased exposure within the prop-wash crater. PBS&J recommended diver investigation of the site to determine whether the exposure was directly related to recent excavation by *Gentlemen of Fortune* or caused by removal of loosely consolidated sediments during Hurricane Rita's passage, and to further assess the extent of impacts to the site.

4.5.5 2007 Diving Investigations

When PBS&J arrived at *New York* in October 2007, site conditions had changed considerably since the May remote-sensing survey. In the intervening months, *Gentlemen of Fortune* had continued excavation of the site, uncovering a 100-ft-long (30-m) section of the lower hull forward of the engine (Figure 45). Due to this unexpected level of site exposure, the decision was made between PBS&J and the COTR to extend dive investigations an extra day. The additional time was used to produce as complete a site map as possible, in addition to the initial goal of evaluating potential hurricane impacts. Thirty-five dives totaling over 33 hours were spent on-site from October 7 to October 10. Bottom visibility was the best of any of the studied wrecks, generally between 5 and 10 ft (1.5–3.0 m). Underwater photographs, along with DIDSON and sector-scan data, were collected in order to supplement creation and interpretation of the site map.

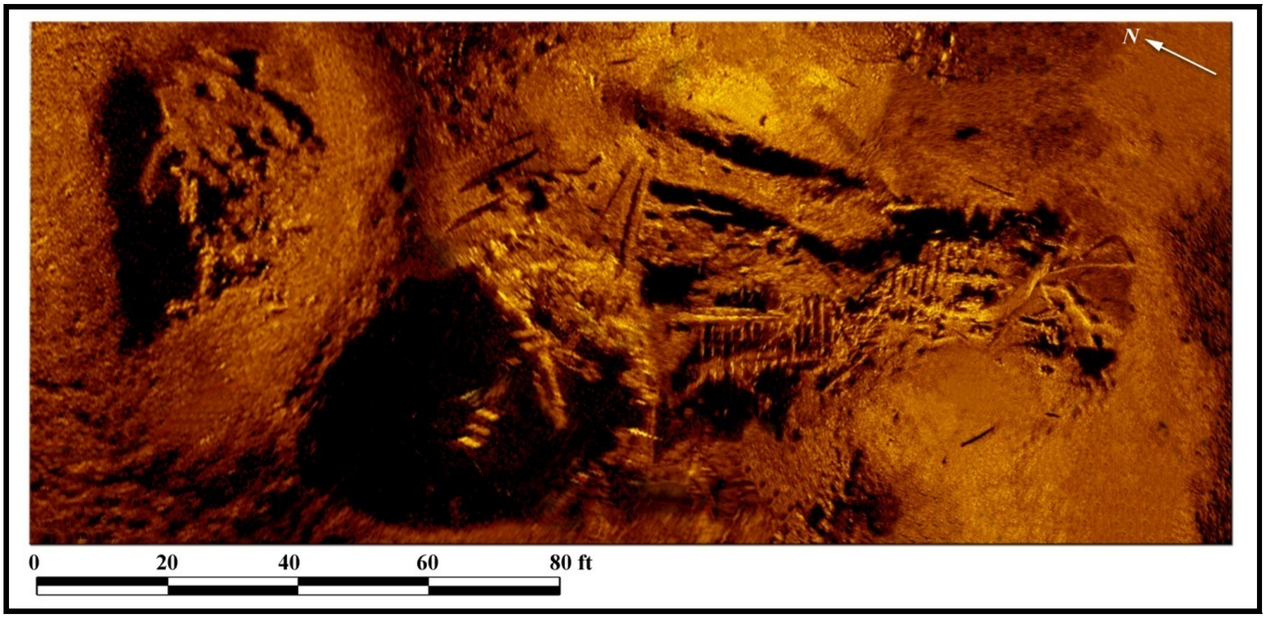


Figure 45. Sector-scan sonar imagery of *New York*.

Almost 125 ft (38.1 m) of continuous wreck remains were exposed, from just aft of the engine compartment and forward to the bow (Figure 46). Site depths ranged from 56 ft (17.1 m) at the top of the engine cylinder to 65 ft (19.8 m) at the base of the prop-wash crater. The bow was identified in part by the ca. 15 ft (4.6 m) of anchor chain running in a line from underneath the southern end of the wreck to the edge of the prop-wash crater, where it became buried again. This chain was concreted and elevated off the seafloor by about 2 ft (0.6 m) at certain points, indicating it was taut when the vessel went down. At the time of its sinking *New York* was reported to have been at anchor, attempting to ride out the storm, when the hurricane-force winds changed direction and caused the vessel to fatally swing into the wave trough. A secondary, smaller magnetometer anomaly was recorded approximately 300 ft (91 m) southeast of the wreck site, in the general direction of the chain's orientation. The anomaly source may be the buried ship's anchor, though that was neither confirmed nor further investigated.

The wreck was broken cleanly in half, just forward of the engine. The forward (southern) half consisted of the lower hull, up to just below the turn of the bilge. Extant features included portions of the keel, frames, futtocks, ceiling planking, outer hull planking, and copper sheathing (Figure 47a–c). Most of the wood in this area was extremely well preserved; *teredo* damage afflicted primarily only the upper frame ends, while unconcreted square-cut spikes and woodworking tool marks were still preserved in the lower, recently excavated areas of the hull.

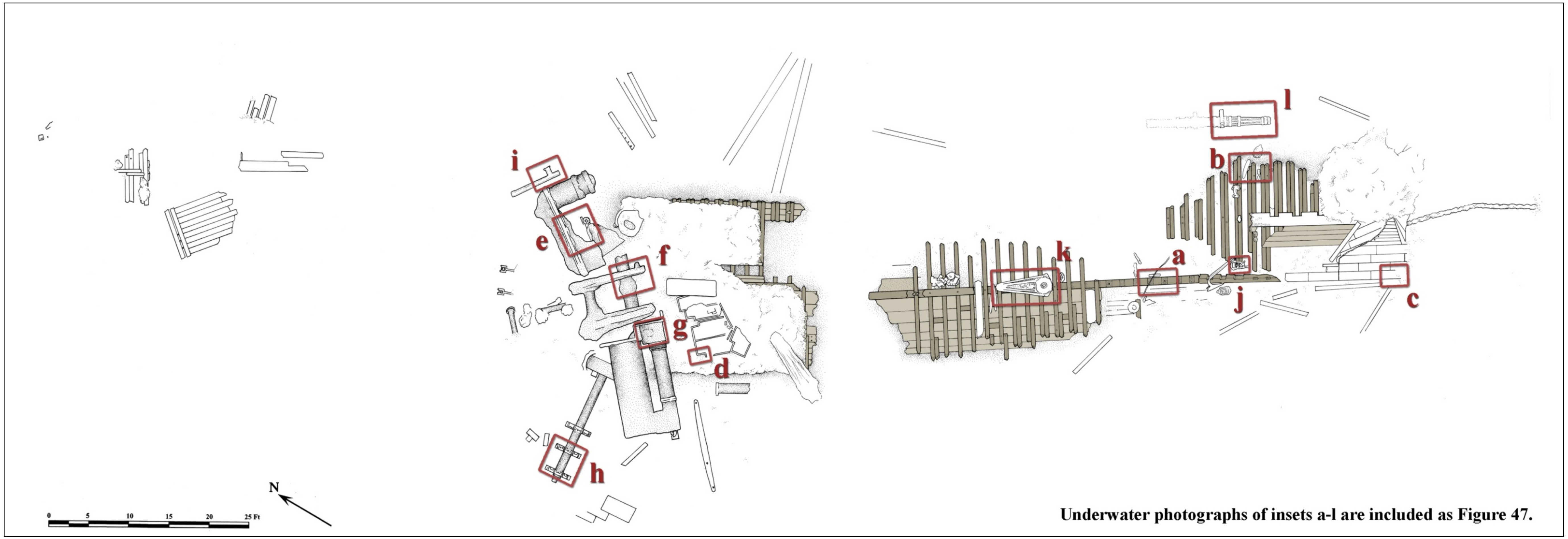


Figure 46. *New York* site plan (drawn by Amy Borgens).

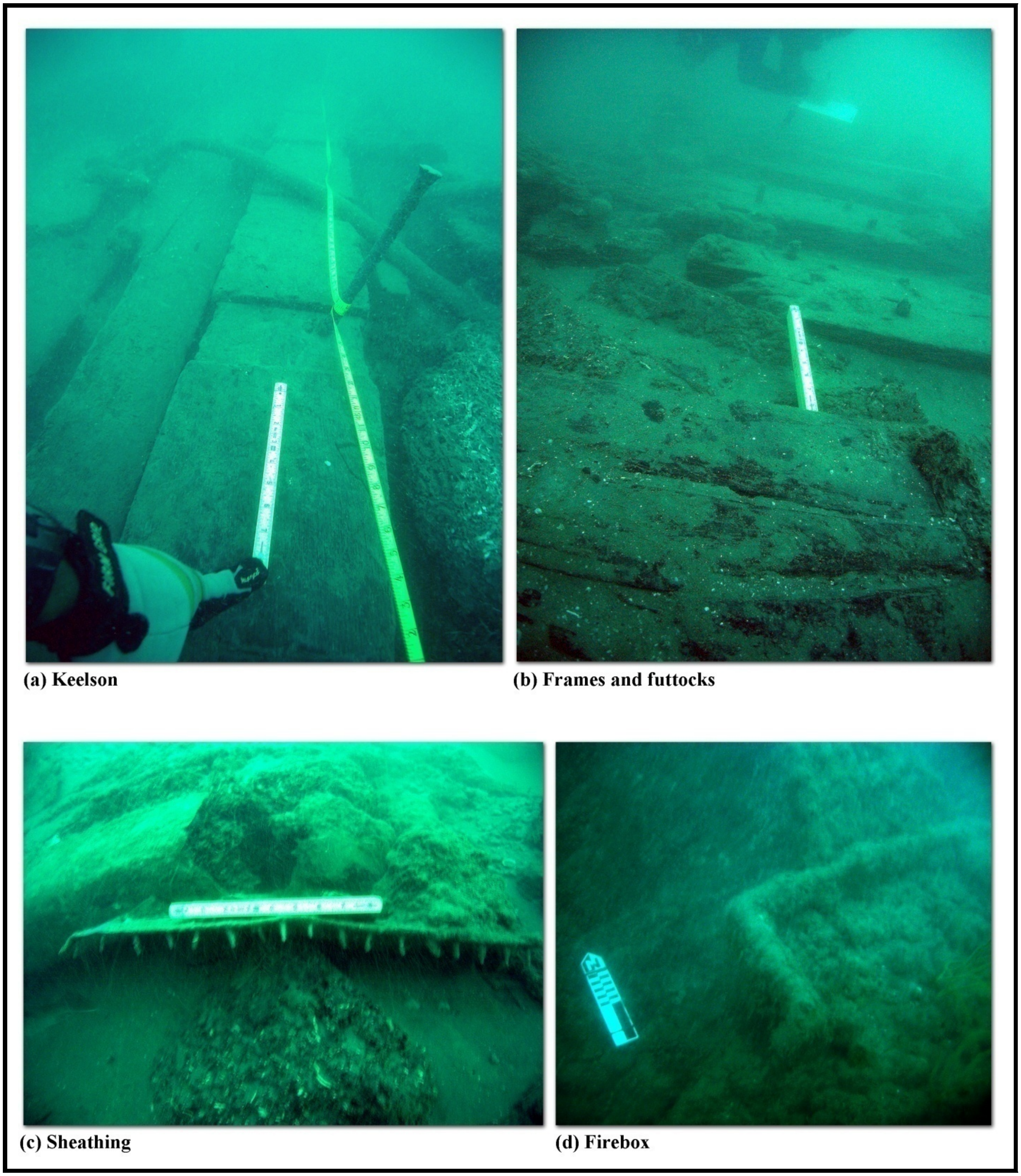


Figure 47. Underwater photos of *New York*.

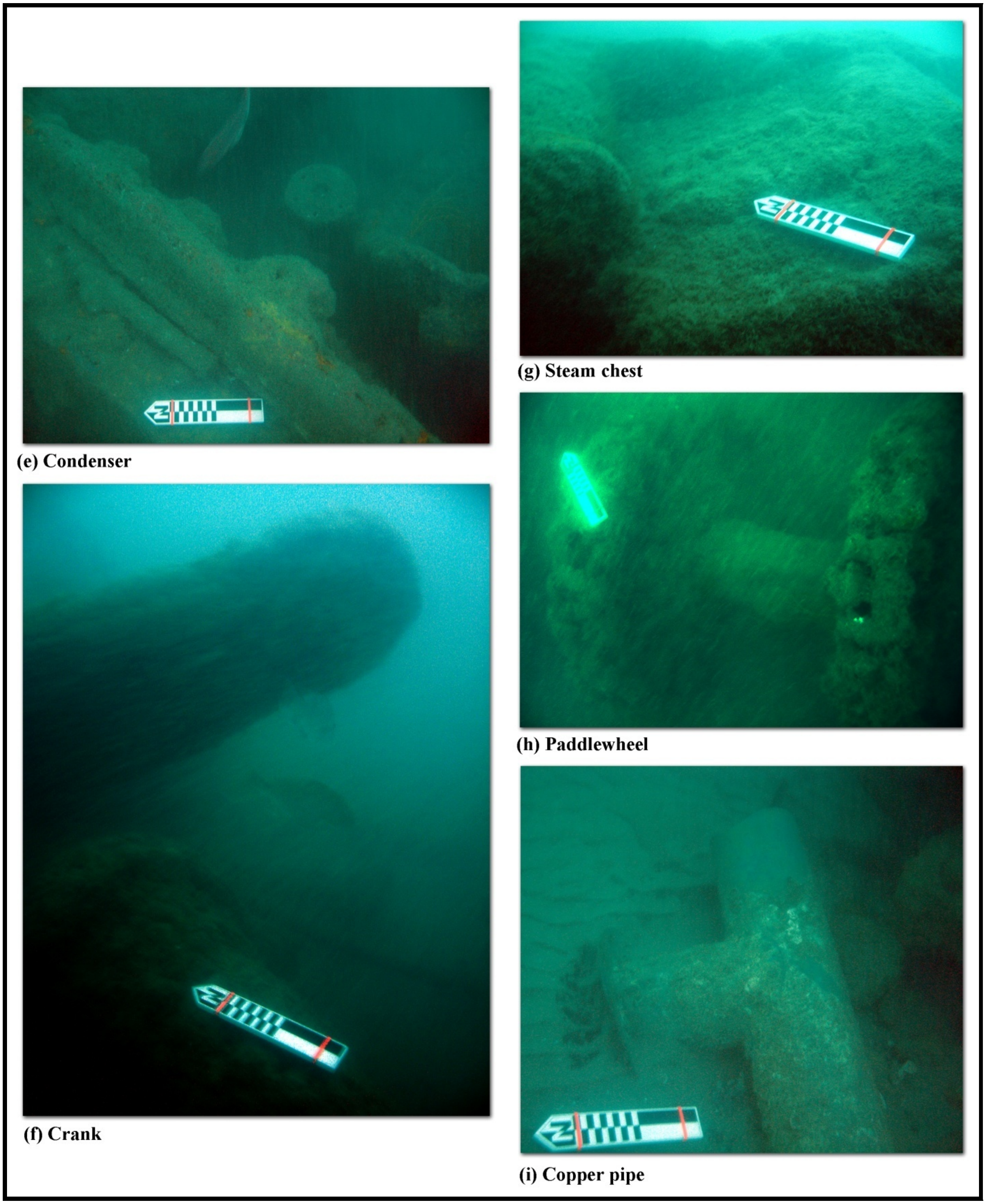
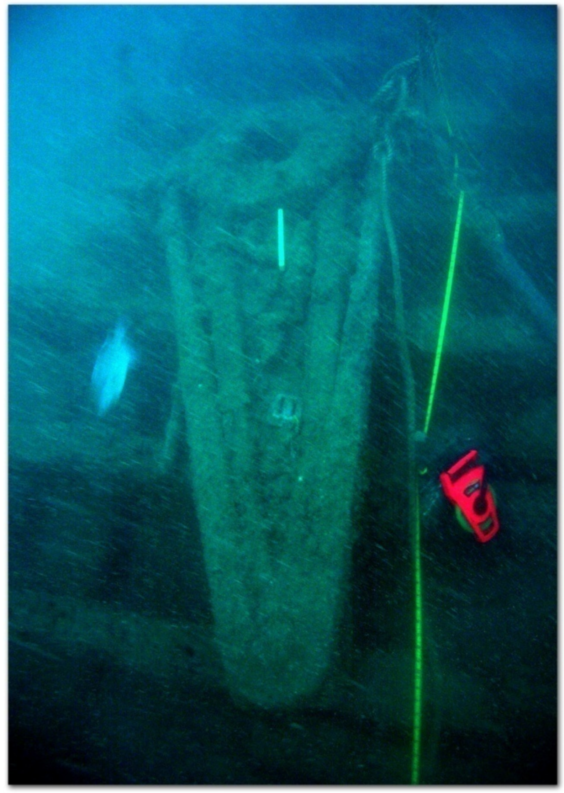
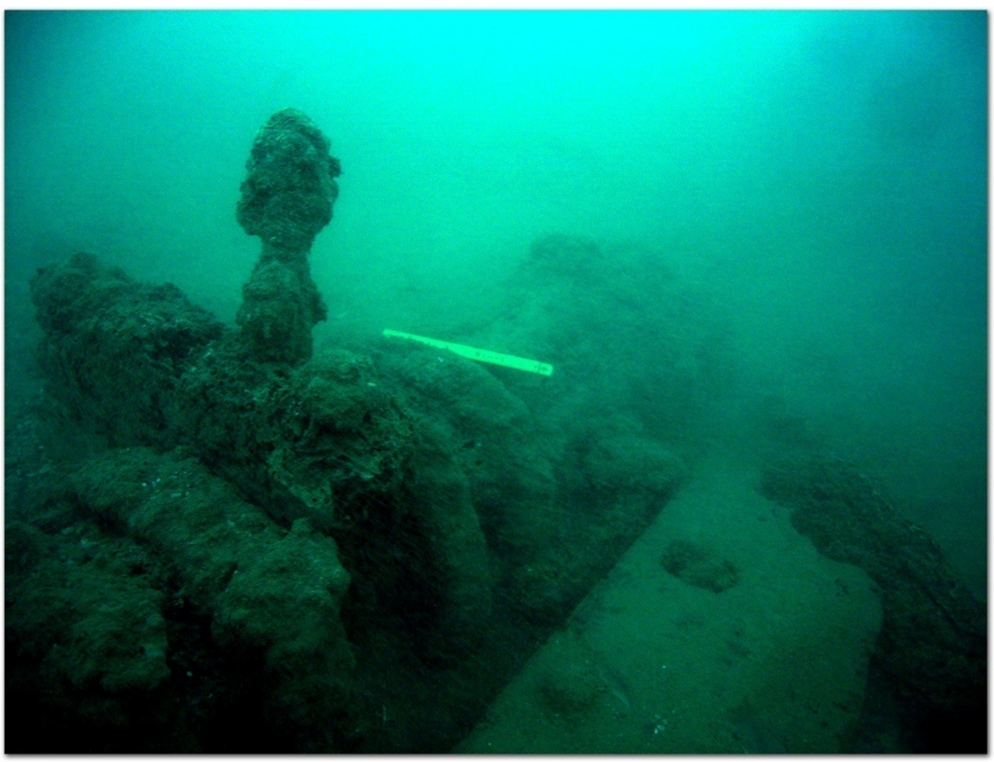


Figure 47. Underwater photos of *New York* (continued).

(j) Sheaves



(k) Object A



(l) Windlass

Figure 47. Underwater photos of *New York* (continued).

Aft (north) of the break in the hull, immediately forward of the steam engine, was another section of keel, framing, ceiling, and outer hull planking, overlain by a more than 1-ft-thick (0.3-m) deposit of amorphous concretion. This concretion covered an area approximately 20 x 20 ft (6.1 x 6.1 m) and contained a few scattered bricks and, atop its center, a group of roughly rectangular iron frames arranged side-by-side (Figure 47d). This area is believed to be the remnants of the boiler fire boxes.

Immediately adjacent to the firebox concretions, to the north, were the remains of the crosshead steam engine. All engine features previously identified (Irion and Ball 2001) remained extant, including the air pump, condenser (Figure 47e), cranks (Figure 47f), steam chest (Figure 47g), and cylinder. These features are the highest points on the wreck and, therefore, had the highest degree of corrosion due to their increased exposure above the seafloor. What remains of the engine is lying over on its starboard side and is heavily concreted and broken apart. The starboard paddlewheel shaft (Figure 47h) lies next to and partially underneath the cylinder, and the air pump lever is lying on the opposite side, adjacent to the steam chest. Numerous disarticulated copper pipes, flanges, rods, and valves litter the seabed surrounding the engine (Figure 47i). The spatial relationship between the engine and boiler fireboxes was another indicator of the wreck's bow and stern orientation. The only known images of *New York* (see Figure 43) illustrate the smokestack forward of the engine A-frame.

Twenty feet farther north of the engine, and slightly to the port side of the centerline, was a second prop-wash crater approximately 40 ft (12.2 m) in diameter. Within this crater were four disarticulated and partially buried groupings of frames, ceiling, copper sheathing, and outer-hull planking. These wood features also were in an excellent state of preservation and appeared to have been very recently exposed. As was later discovered, *Gentlemen of Fortune* had been conducting site excavations only a few days before our arrival.

Virtually no artifacts were observed in situ. A small number of rigging sheaves were grouped on either side of the keel near the bow (Figure 47j), and numerous iron and copper fasteners were scattered throughout the wreck. Twenty feet forward of the hull break was an iron object (Figure 47k) that PBS&J has been unable to identify (hereafter referred to as Object A). It was approximately 6 ft (1.8 m) long, with a circular disk at one end inside doubled bands that tapered together at the opposite end. It was oriented directly on top of and in-line with the keel but did not appear to be attached to it. Object A's general shape strongly resembled an engine crank; however, there was no attachment point for a connecting rod and pin assembly at the narrower end, and it was considerably smaller than the cranks observed with the engine remains. A barrel windlass lay just off the port side of the forward frame ends (Figure 47l). All other artifacts in the exposed areas of the wreck had been previously removed by *Gentlemen of Fortune*. In December 2008, PBS&J was invited by *Gentlemen of Fortune* to examine and inventory the artifacts collected to that point. A catalog of those artifacts is presented in Appendix C.

4.5.6 Sedimentology

Because the box coring collection device was previously lost during diving on *Castine*, an alternate collection method was employed at *New York*. Three 2-ft-long (0.6-m), 2-inch-diameter (5.1 cm) PVC pipes were hammered into the substrate and capped. Two of the cores were collected outside of the main wreck site (at 53 ft [16.2 m] and 56 ft [17.1 m] below water line [bwl], respectively), and the third was collected underneath *New York*'s hull, in an area scoured out by prop wash excavations (63 ft [19.2 m] bwl). Each core was then extracted and analyzed in the lab. Particle-size results for each core are presented in Table 15. Sediment stratigraphy was uniform within each of the three cores; therefore, they were not separated into levels. Zones of fine sand are present at 53 and 56 ft (16.2 and 17.1 m) bwl. The core collected at 63 ft bwl (19.2 m) is predominantly silt, though also with an increase in clay content.

Table 15

SS *New York* Particle-size Results

Sample	Provenience	% Gravel	% Sand	% Silt	% Clay	Mean phi	Classification
1-*New York*	53 ft bwl	1	90.5	5.5	0	2.83	Fine sand
2-*New York*	56 ft bwl	0	96	2	0	2.86	Fine sand
3-*New York*	63 ft bwl	0	18	56	7	5.47	Medium silt

As with the particle size results recorded at *Gulf Tide* (see Section 4.4.6), the upper layers of fine sand surrounding *New York* indicate a high likelihood of localized redistribution of sediments resulting in at least partial site burial. This process is consistent with *Gentlemen of Fortune*'s repeated observations of the site's tendency to rebury shortly after exposure, even in non-storm years (see Section 4.5.7). Interestingly, the core data taken from 63 ft bwl show a significant transition from sandy soils to predominantly silts with a mixture of sand and clay. This is consistent with diver observations of exposed areas underneath the wreck structure (within prop-wash excavation holes). In these areas divers noted that the bottom of the vessel hull was situated on a denser, more cohesive, clay-like substrate. These observations were further corroborated by *Gentlemen of Fortune.* According to site observations recorded by the group on flat areas of the site (Hebert 2008), sediment stratigraphy consists of approximately 1.5 ft (0.46 m) of sand covering 1 ft (0.3 m) of intermediate clay, below which is the "Beaumont clay" (at approximately 58 to 59 ft bwl [18 m]). The layer referred to as "Beaumont clay" by *Gentlemen of Fortune* is likely this denser layer of cohesive Holocene marine silts, as documented by the core data. *Gentlemen of Fortune* observed that underneath heavy sections of the wreck this denser layer gets pushed deeper (to about 64 ft [20 m] bwl). This observation is consistent with other published studies on sediment bed formation processes:

> Means and Parcher (1963) suggested that the bonding of clay particles by interstitial water produces a resistance to movement. When this bonding is broken by physical disturbance of the sediment, less viscous water is introduced into the intergranular spaces and the strength is reduced. For sensitive clays, there is a high resistance to deformation up to a critical stress where remolding occurs. Once the chemical bond is broken the grains are easily displaced to form a denser structure. (Morelock and Bryant 1972:186)

According to maps published by McClelland Engineers (1979:Plate 2A), Pleistocene soils formed under subaerial conditions during the Late Wisconsin glacial period are less than 20 ft (6.1 m) beneath the modern mudline in the vicinity of *New York*. McClelland Engineers (1979:Plates 3A, 4A, 5A) mapped the shear strength of soils at the seabed in the range of 0.1 to 0.2 ksf, which they qualitatively describe as very soft; however, *New York* falls in a region of their map where boring coverage was sparse. The shear strength is mapped as 0.4 to 0.6 kfs (soft) at a depth of 10 ft (3.0 m) below the seafloor and as 0.6 to 0.8 ksf (firm) at a depth of 20 ft (6.1 m). The OTRC (2004) map constructed using method 1 (see description in *Castine* sedimentology results, Section 4.2.6) shows soil shear strengths surrounding the location of *New York* as 0.2 ksf (soft) at the mudline, 0.5 ksf (soft) at 5 ft (1.5 m) below the seafloor, and 1.1 ksf (stiff) at 10 ft (3.0 m) below the seafloor. According to the OTRC maps, *New York* is located within a sand polygon from the mudline to 10 ft (3.0 m) below the seafloor, meaning their shear strength map constructed using method 2 did not calculate shear strengths in the area of *New York*. OTRC's data on sand content match PBS&J's coring data for the upper levels of the site, but not for the sediment underlying the wreck. The orientation of *New York* on top of a cohesive layer of Holocene marine silts, and the tendency for the majority of its structure to rebury under a protective layer of sand, implies that the wreck has reached its maximum depth of natural subsidence.

4.5.7 Impact Assessment

Hurricane Rita passed 34.4 mi (55.4 km) east of *New York* as a Category 3 storm at 1:00 A.M. on September 24, 2005. Peak sustained winds over *New York* were estimated by Oceanweather, Inc.'s (2006) hindcast model at 69 mph (30.9 m/s) from a direction of 265 degrees. The maximum significant wave height over *New York* was estimated at 18.0 ft (5.5 m) from a direction of 98 degrees. At peak storm conditions over the site, maximum bottom currents of 5.6 mph (2.5 m/s) struck *New York* along its port side and slightly from the bow at an angle of 72 degrees relative to the ship's orientation. At intervals of 7.75 seconds, the current reversed direction 180 degrees beneath the wave troughs to a velocity of –1.6 mph (–0.7 m/s), then peaked again 7.75 seconds later at 5.6 mph (2.5 m/s) in the forward direction beneath the next wave crest. The amplitude of velocity change from forward to reverse, on an interval of 7.75 seconds, was 7.2 mph (3.2 m/s). Given the difference in density between seawater and air, the damage potential represented by the maximum forward water velocity is equivalent to that of a 158-mph (70.6-m/s) wind or analogous to an F3 tornado.

Archaeological knowledge of *New York* predating Hurricane Rita consisted primarily of the 1997 site investigations and anecdotal information provided by *Gentlemen of Fortune*. Those data confirmed the presence of substantial elements of *New York*'s crosshead steam engine, but very few other exposed vessel remains beyond a small number of worm-eaten frame ends. By the time of PBS&J's 2007 investigations, the site's appearance had been significantly altered; over 100 ft (30 m) of the site was uncovered, revealing most of the vessel's lower hull plus additional features associated with the engine. Few of these impacts, however, appear to have been induced by recent hurricane activity, but were instead the result of site excavations conducted by *Gentlemen of Fortune* since the passage of Hurricane Rita.

Indicators of *Gentlemen of Fortune*'s activities were evident in the remote-sensing data and observed during the diving investigations. Side-scan and sector-scan imagery showed one or more symmetrical bowl-shaped depressions centered on various elements of the wreck—clear evidence of prop-wash excavations rather than a natural removal of sediments. Several intrusive excavation-related materials were also left behind on-site, including plastic artifact collection buckets, tape measures, buoys, and line. A small, modern plow anchor was observed near the bow, where it had snagged and dislodged a 10-ft (3.0-m) segment of the keel along its fore and aft scarf joints (see Figure 46). Apart from this example, damages to the remaining wooden hull features and engine machinery appeared to be minimal. There was no indication that elements of the ship's hull had been actively damaged or disarticulated during the excavation activities. Furthermore, all materials that had been recently exposed exhibited a high degree of preservation. Wood, particularly the more substantial structural elements like the keel and frames, appeared to retain significant density, and exhibited almost no indications of ship-worm damage. Many iron fasteners seen protruding from planking showed either no signs of concretion or concretion formation to a much smaller degree than would be expected of a mid-nineteenth-century shipwreck (although this observation was not universal; many iron objects, particularly near the engine, did exhibit more-typical degrees of corrosion and concretion). Of course, the exposure of these wreck features creates the catalyst for accelerated decomposition of the site. The *teredo*-damaged ends of previously exposed frames and the complete absence of any other wooden vessel remains above the sediment line provide all the evidence needed of the fate that awaits any parts of the wreck subjected to continued prolonged exposure in the aerobic water column.

No personal items and very few small objects associated with the ship's construction or operating mechanisms were observed during the 33 combined diver-hours spent on-site. Though the scale of *Gentlemen of Fortune*'s artifact collecting was unknown at the time of PBS&J's investigation, the salvage group granted a request to examine and inventory the recovered artifacts at their facility in New Iberia, Louisiana. The results of that visit are presented in Appendix C.

Concurrent with PBS&J's examination of the artifact collection, *Gentlemen of Fortune* obligingly shared their site plan and copious field notes, including detailed documentation of their own activities and of the varying site conditions since their discovery in 1990. Their cumulative observations indicate that *New York* exists in a state of environmental equilibrium that should continue to protect the remaining site features in the future regardless of hurricane activity. Unless otherwise noted, the following information was obtained from interviews with *Gentlemen of Fortune*'s principal members, Avery Munson, Gary and Renée Hebert, and Craig DeRouen, in December 2008.

After discovering *New York* in 1990, *Gentlemen of Fortune* revisited the site in 1991, 1994, 1995, 1996, 1998, 1999, and 2004–2009. Excavations were first conducted utilizing a 2-inch-diameter (5.1-cm) dredge, until 1994 when the group switched to a 30-inch (76.2-cm) prop-wash deflector powered by a 465-horsepower engine and 28-inch (71.1-cm) propeller. In 1994 the full width of framing was exposed from Object A (see Section 4.5.5, Figure 46, and Figure 47K) to the forward end of the hull break (an area about 25 ft [7.6 m] in diameter), but the lower hull remained buried except in small areas. Though *Gentlemen of Fortune* returned repeatedly to the site over the next decade, larger-scale excavations did not begin until 2005. That year, the group ended their field season on August 13 (six weeks before Hurricane Rita made landfall), leaving a 2–3-ft-deep (0.6–0.9-m), 60-ft-diameter (18.3-m) prop-wash crater centered on the engine. *Gentlemen of Fortune* returned to the site nine months after Hurricane Rita, in June 2006, and found that the site had been reburied to its prediscovery depths, "as if we [*Gentlemen of Fortune*] had not worked it at all."

Between June and August 2006, the wreck was excavated down to the hull planking from Object A to the aft end of the break, and to slightly below the hull in the break. Maximum water depths reached 64 ft (19.5 m) at the bottom of the excavation crater. Other than having been reburied since the 2005 excavations, there was no noticeable change to the site resulting from Hurricane Rita. Between August 2006 and February 2007, the site was again covered by silt, but to a lesser extent than was observed in previous years. Two to 3 ft (0.6–0.9 m) of sediment were redeposited in the break, but only 1–1½ inches (2.5–3.8 cm) of reburial occurred on top of the hull. This was the same approximate site condition when PBS&J conducted its remote-sensing survey in May 2007. *Gentlemen of Fortune* continued excavations through the summer and fall of 2007, resulting in the extent of wreck exposure observed during PBS&J's October 2007 site investigation.

Between 2007 and 2008, silt once again covered the site to near prediscovery depths. The break had filled in up to the hull, and the hull had filled in up to the frame ends. *Gentlemen of Fortune* reexcavated the site to the 2007 extents, plus an additional distance of 25 ft (7.6 m) aft of the engine. The port paddlewheel was observed approximately 1,000 ft (305 m) east of the main wreckage, and a magnetic anomaly was also excavated approximately 300 ft (91 m) east of the wreck. A 30-ft-diameter (9.1-m), 3-ft-deep (0.9-m) area was uncovered, revealing what *Gentlemen of Fortune* believe to be iron bracing associated with the ship's rigging. Towards the end of the 2008 season, the boiler was discovered approximately 150 ft (46 m) west of the engine. In addition to the boiler, the 40-ft-diameter (12.2-m) prop-wash crater uncovered several disarticulated pipes approximately 15 inches (38.1 cm) in diameter and 10 ft (3.0 m) long strewn around and on top of the boiler and a 4-ft-diameter (1.2-m), 10–12-ft-long (3.0–3.7-m) section of the smokestack. The bottom of the boiler was approximately 8 ft (2.4 m) below the natural seabed.

The year 2008 was also notable for the trio of storms that swept into the GOM (Figure 48). The first was Tropical Storm Edouard, which passed 26.5 mi (42.6 km) northeast of *New York* on August 5. Next, Hurricane Gustav passed 152 mi (245 km) northeast of *New York* on September 1. Finally, Hurricane Ike, the most destructive of the three storms and the third costliest hurricane to ever make landfall in the United States, passed 27.6 mi (44.4 km) southwest of *New York* on September 13. Though an analysis of the effects of these storms was outside the original scope of this study, the subsequent site observations recorded by *Gentlemen of Fortune* provide a unique opportunity to compare the recurring effects of multiple hurricane passages near *New York*. What these data indicate is that, at worst, rather than being destructive events, hurricanes generally accelerate the natural reburial of this site that occurs even during nonhurricane years.

Gentlemen of Fortune temporarily halted their 2008 excavations as Tropical Storm Edouard approached in August. When they returned following the storm they found that at least 1–2 inches (2.5–5.1 cm) of sediment had been redeposited across the entire site, with thicker deposits in the deeper excavation holes. The only negative impacts to the site were a small number of already loose and disarticulated timbers that had been moved approximately 20 ft (6.1 m) west. *Gentlemen of Fortune* were forced to abandon their excavations of the site again when Hurricane Gustav formed, but upon returning found that that storm had no measurable effect on site formation. Hurricane Ike provided the most dramatic results, not only refilling excavation holes to their natural depth, but also depositing an additional 12–14 inches (30.5–35.6 cm) of new sediment across the entire site. Divers examined the surrounding seabed up to 150 ft (46 m) away from the wreck and found the sediment deposition was consistent. Unlike in other years, when the redeposited sediments were characterized by a base of about 2 inches (5.1 cm) of clay underneath a layer of unconsolidated silts, the new sediments deposited after Hurricane Ike consisted of a thin surface layer of a highly consolidated and brittle sand/silt mixture on top of about 12 inches (30.5 cm) of soft, sticky mud.

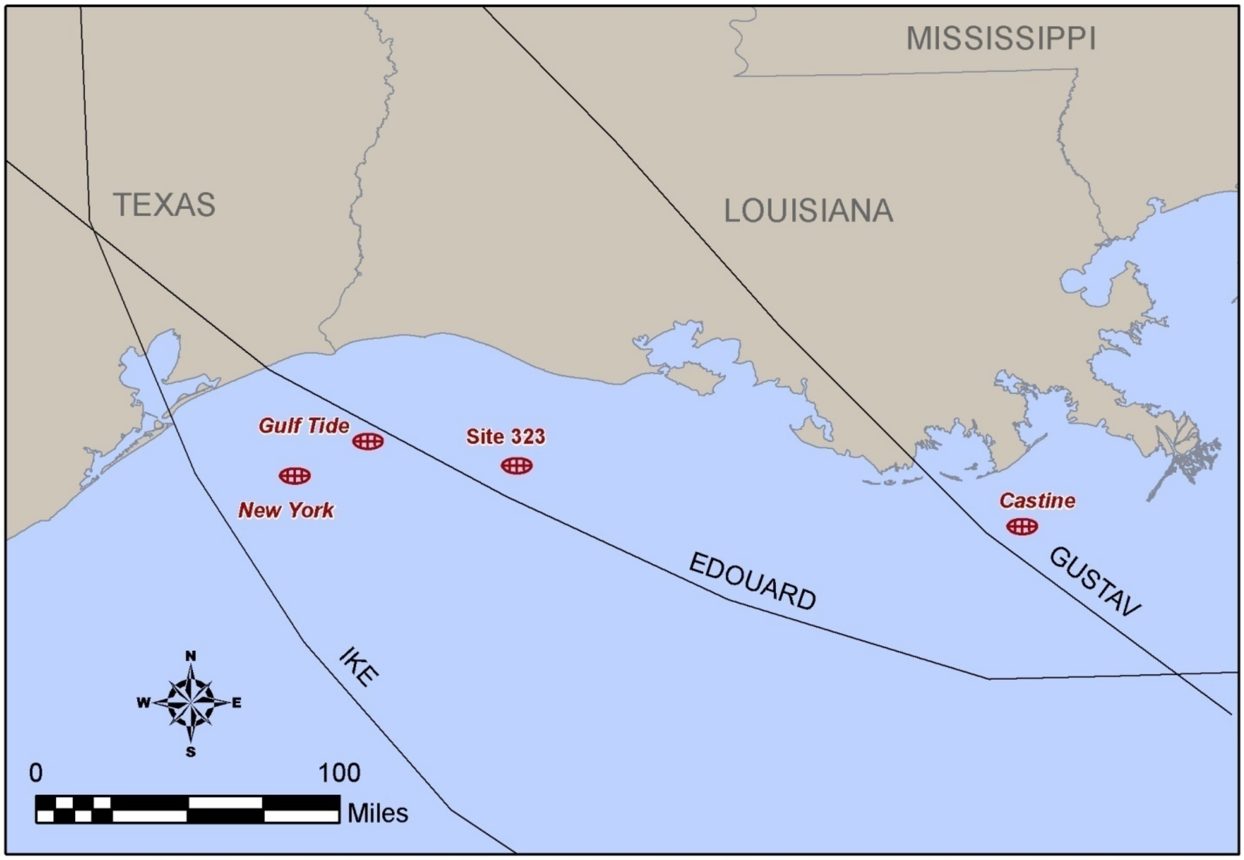


Figure 48. 2008 GOM storms.

This tendency for the site to return to prediscovery burial depths had been observed following virtually every field season since the first excavations in 1994. Within only a few months, excavation holes varying from 6 inches (15.2 cm) to over 3 ft (0.9 m) deep would completely refill and bury the underlying wreckage. This is the same result that was observed following Hurricane Rita. Since 1994 there have been only two variations to this pattern: between the 2006 and 2007 seasons, when only 1–1½ inches (2.5–3.8 cm) of sediment were redeposited on-site by Hurricane Edouard; and following Hurricane Ike in 2008, when the site returned to prediscovery depths plus an *additional* 12–14 inches (30.5–35.6 cm) of sediment accumulation. This repeated return to equilibrium has served to protect the remaining wreck features and has likely been a significant factor in the high level of wood and iron preservation observed across the site. Therefore, it seems that Hurricane Rita, and any other strong storm events of the past two decades, have had a counterintuitive beneficial effect on site preservation. Continued excavations of the site can reverse this trend, however. Though recently excavated areas of the wreck exhibited a relatively high degree of preservation, the degradation of these same features can be expected to accelerate with continued or repeated exposure in the oxygenated water column. Furthermore, future prop-wash excavations might undermine portions of the wreck. If the silt/clay layer upon which the site rests were partially removed by prop-washing, localized sections of the hull might collapse into the resulting hole. Over time this process could result in differential subsidence and the associated structural weakening of the wreck.

4.5.8 National Register Assessment

New York was associated with some of the earliest and most important individuals in the economic and technological development of commercial steam navigation in the U.S. It was also one of the primary vessels in two of the first coastal steamship lines, and during its brief career rose to prominence as arguably the most luxurious Gulf Coast steamship of its day. Today, the archaeological remains of *New York* provide a tangible link both to that era and to those prominent individuals, and further embody a significant technological transition period in marine steam engine development.

New York was built by William H. Brown, and its crosshead steam engine was produced by James P. Allaire. A renowned engineer and businessman, Allaire amassed and lost several fortunes during his lifetime. He began as a protégé and successor to Robert Fulton and was onboard Fulton's history-making voyage from Hoboken to Albany on *The Steamboat* (also known as *The North River Steamboat* and *Clermont*) in 1807, which established the first commercially viable steamship service. After Fulton's death in 1815, Allaire purchased the former's engine works in Jersey City, an operation that was eventually moved to New York and evolved into the Allaire Works. By the early 1820s Allaire had also purchased and expanded the Howell Works, a sprawling iron foundry complete with a bakery, department store, school, church, wheelwright shop, blacksmith's shop, carriage house, worker housing, and Allaire's own mansion (Pepper 1957). From 1835 to 1840, Howell Works was the largest foundry in the U.S., employing 500 workmen and their families, and it exists today as a living history museum renamed Allaire Village, located within New Jersey's Allaire State Park.

By this time, Allaire had also established himself as the finest marine engineer in the country. He had obtained over half of the New York City engine-building business, including a contract to cast the brass cylinder for *Savannah*, the first steam vessel to cross the Atlantic (Coombe 1986; Pepper 1957). Though he was not the inventor, Allaire was also credited for his contributions to the development of the first compound marine engine (Pepper 1957).

Allaire's shipping interests were not limited only to the engineering side. His entrepreneurial ambitions also led to his involvement with the more commercial aspects of the shipping industry. In the 1830s Allaire partnered with Charles Morgan, John Haggerty, and John and Benjamin Aymar to establish the New York and Charleston Steam Packet Company, which provided regularly scheduled steamer service between New York and the southern states. This company was the first steam packet operation in the country.

Charles Morgan was himself the principal owner of *New York*. After its construction, Morgan added this ship to the New York and Charleston line, joining the steamers *Columbia* and *Home.* After Allaire suffered several personal and financial hardships, Morgan took over ownership of the company and reorganized it as the Southern Steam Packet Company. The steamer line flourished under Morgan's leadership, and he soon expanded his operations to the Gulf Coast. In addition to establishing the first coastal steamship line along the eastern seaboard, Morgan also established the first such service in the GOM; in 1837, the Southern Steam Packet Company began running passengers and cargo between Galveston and New Orleans. *New York* joined Morgan's Gulf operations in 1839 and remained there until its demise in 1846. That was also the year that Morgan was awarded a contract with the United States Post Office to deliver mail to the newly annexed State of Texas. One of the passengers onboard *New York*'s final voyage was Daniel J. Toler, former postmaster general of Texas, who was on a return trip from Washington, D.C., with the official Federal documents regarding Texas's new postal responsibilities. Though Toler survived the wreck, his cargo went down with the ship (Baughman 1968:40).

For his part, Charles Morgan later became one of the most prominent figures in the establishment of Gulf Coast steamship and railroad commerce. He developed the port at Indianola in Matagorda Bay, Texas, and founded the Morgan Iron Works Company in New York City, which became one of the country's leading producers of marine steam engines in the mid-nineteenth century (Baughman 1968:56). Following the Civil War, Morgan founded the Louisiana and Texas Railroad and Steamship Company, which created a vast network of steamer routes and rail lines connecting the Gulf Coast to the Mississippi Valley, northern Latin America, and the U.S. Atlantic and Pacific coasts (Baughman 1968). Because of the prosperity that he brought to the region, the Louisiana city of Brashear was renamed Morgan City in his honor in 1876.

James P. Allaire and Charles Morgan were giant figures in the advent of steam-powered coastal commerce in the United States. Allaire was a technological innovator of marine steam engines, and his partnership with Morgan brought on the first commercial steam packet service in the country. Morgan expanded that operation to include rail and steamer service to the Gulf Coast, leaving an indelible mark on the economic development of that region and the United States as a whole. *New York* was one of the principal vessels involved in both of these shipping lines. Due to these associations, *New York* is eligible for the National Register under Criteria A: *associated with events that have made a significant contribution to the broad patterns of our history*; and B: *associated with the lives of persons significant in our past.*

As part of Charles Morgan's Atlantic and Gulf Coast steamship lines, *New York* was also one of the earliest examples of a purpose-built steam packet. As such, its wrecked remains provide a rare opportunity to document and study the construction characteristics of a vessel of this type and time period. Though a significant number of the personal and smaller ship-related artifacts have been removed by *Gentlemen of Fortune*, a substantial amount of the lower hull up to the turn of the bilge remains in situ. Further archaeological investigation of these features could yield valuable knowledge of the materials, methods of construction, and design practices of a mid-nineteenth-century merchant steam vessel. Furthermore, there are only two known images of *New York,* both profile-perspective paintings of unknown provenience or accuracy. Further archaeological investigation is the only opportunity to determine any quantifiable construction detail of this historically significant ship.

Perhaps the most significant feature of *New York*'s design and construction is its Allaire-built crosshead steam engine. The crosshead engine, alternately known as a square, steeple, or guillotine engine, was one of the earliest types of marine steam engines developed and was in use from the early 1800s through the 1840s. It was a direct descendant of the earliest Fulton-type steam engine and also a technological precursor to the vertical walking beam engine that was widely used in the second half of the nineteenth century (Holly 1995). The crosshead engine represents an important phase in the evolution of marine steam engines and in the shipbuilding and industrial history of the United States. Unfortunately, comparatively little is known about the actual real-world construction and operation of these engines, because there is only one known surviving example. In 1993, archaeologists recovered the remains of *Columbus*, a Chesapeake Bay steamer that was built in 1828 and sank in 1850. Those excavations recovered part of *Columbus*'s crosshead engine, including the cylinder with piston, crankshaft bedplate, condenser, valve chests, steam piping, valve rocker shaft, air pump, and the starboard paddlewheel shaft. Diagnostic elements of the valve system, connecting rods, and the crosshead itself were not recovered (Irion and Anderson 1995). As a result, understanding of the design elements of the crosshead-type engine, particularly the distinguishing cylinder, steam chest, and valve assembly, remains theoretical and speculative (Holly 1995). *New York* represents the second known crosshead engine in existence, and its continued study may illuminate many of the unknown characteristics of this technologically significant engine type.

Because of the archaeological potential of *New York*, the site is also eligible for the National Register under Criteria C: *embodies the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic value, or that represent a significant and distinguishable entity whose components may lack individual distinction*; and D: *has yielded or may be likely to yield information important in prehistory or history*.

5.0 DISCUSSION

This study has resulted in several conclusions that should have implications for the future management of submerged historic shipwrecks on the shallow Continental Shelf in the GOM. The effect of hurricane waves on the seafloor environment has been quantified, allowing one to visualize the substantial forces affecting shipwrecks as hurricanes pass nearby. However, the damage caused by Hurricanes Katrina and Rita to the primary study wrecks was substantially less than anticipated based on the level of damage reported for 37 artificial reef vessels in waters offshore of Florida (see Table 3). Exploring the reasons for this observation has led to formulation of a hypothesis that the level of damage to a shipwreck (or artificial reef vessel) is relatively high after the first one or two hurricane passages, and is progressively less following later storms. The preservation of articulated wooden hull and an in situ artifact assemblage on *New York* has demonstrated the potential for burial to provide a high degree of protection from hurricane damage to many more historic wood-hulled vessels in the GOM. Finally, studies of storm damage to petroleum infrastructure demonstrate that hurricanes have the potential to cause damage to shipwrecks that is indirectly anthropogenic in nature. This conclusion has potential implications for the regulation of petroleum industry activities and the management of submerged cultural resources in the GOM.

5.1 Conclusion 1: Hurricanes Generate Substantial Seafloor Forces on the Shallow Continental Shelf in the Gulf of Mexico

Strong and rapidly fluctuating bottom currents and pressure differentials were generated by large waves at each of the primary study sites. When the kinetic energy of a hurricane's wind is converted to waves, the potential energy of those waves, as their height increases, eventually becomes amplified well beyond the original instantaneous energy of the wind. In the case of Hurricane Rita, the geographic extent of substantial bottom currents exceeded that of the hurricane-force winds. The magnitude of force experienced on the seafloor at each primary study site was roughly equivalent to a tornado of F3 (*Castine* and *New York*), F4 (*Gulf Tide*) or F5 (Site 323) intensity on the Enhanced Fujita Scale. The depth limit of hurricane damage to shipwrecks exceeds 200 ft (61 m). At that depth, Hurricane Rita generated water particle velocities of equivalent force as an F1 tornado at distances of at least 46 mi (74.1 km) to the left and 92 mi (148.2 km) to the right of its track. Pipeline damage reports suggest the depth limit of hurricane damage to shipwrecks might be close to 300 ft (91 m).

5.2 Conclusion 2: Damage to Primary Study Wrecks Was Substantially Less Than Anticipated based on the Level of Damage Reported for Many Artificial Reef Vessels

Only one of the four primary study sites, Site 323, exhibited obvious structural damage following Katrina and Rita, and this seemed relatively minor compared to many of the accounts from artificial reef vessels (see Table 3). Based on those examples, the authors anticipated a much higher level of new damage than was observed.

The authors anticipated that as sunken vessels deteriorate with age, they should become more susceptible to damage in the form of structural collapse. Yet the study wrecks (with the possible exception of *Gulf Tide*), all of which have been submerged far longer than the artificial reef vessels in Table 3, exhibited less damage following Hurricanes Katrina and Rita than their artificial reef counterparts did following other hurricanes. On the other hand, evidence from artificial reefs suggests that intact hulls sunk recently are very susceptible to major movement and structural damage. The following discussion examines several factors relevant to these seemingly contradictory observations.

1. The level of damage on at least some artificial reef vessels might be greater than would have been the case if the same vessels sank accidently. This possibility was pointed out by Gregg and Murphey (1994). Their rationale is that salvage of internal structures or use of explosives for sinking a ship might reduce the structural integrity and stability of artificial reef vessels resulting in possible bias of damage data as compared to unintentionally sunk vessels where no salvage of structural elements or explosions occurred. Similarly, vessels sunk as the result of violent forces, such as collisions or torpedoes, might also have substantially weakened structural elements that are then more prone to postsinking hurricane damage. For example, the force of landing upside down on a hard substrate might have broken the back of Site 323, thus providing a weak spot that storm damage might then magnify. The World War II–era wreck of *Sheherazade* (see Appendix A) is another example where this might be the case. One torpedo hole (see Figure A-4) appears to be the focus of recent damage radiating across the hull following the 2005 hurricane season.

2. The authors assumed that storm damage should increase proportional to decreasing water depth (over the top of a wreck), because bottom currents increase beneath a hurricane as water becomes shallower (see Figures 20 and 21). However, the average depth of the four primary study sites, 74 ft (22.6 m), is less than that of the artificial reef vessels in Table 3, 98 ft (29.9 m). Based on these facts, one would expect less damage to the artificial reefs, as a group, because the bottom currents would have been less severe on average (depending on the height of the storm waves in each case). That this was not the case indicates that there must be factors at work other than water depth to explain the lesser damage observed at the primary study sites as compared to artificial reef vessels.

3. The area and orientation of a ship's vertical profile determines its degree of exposure to wave-induced currents. A vessel's compass orientation on the seabed affects the angle of incidence of currents pushing against vertical surfaces. The magnitude of forces acting upon a hull is proportional to the sine of their angle of incidence, where a force acting perpendicular to a surface has a 90 degree angle of incidence and a sine of one thus experiences the full force of the current. The level of storm damage should increase in direct proportion to a storm wave's angle of incidence with minimum damage when waves/currents flow parallel to the long axis of a hull (0 degrees) and maximum damage when waves/currents strike a hull broadside (90 degrees). Likewise, hulls having larger areas of exposed vertical surfaces are subject to greater force from the current. Lukens and Selberg (2004) imply by their recommendations that the orientation of a vessel on the seabed is an important factor in how well it can weather a severe storm. They do not provide specific

supporting examples, although they recommend that vessels be sunk with their bows facing the likely direction of oncoming hurricane-force waves.

The average vertical relief for artificial reefs listed in Table 3 is 32 ft (9.8 m); however, their orientation with respect to the hurricane waves causing their damage is unknown. Of the four primary study wrecks, only *Castine* and Site 323 have large contiguous areas of vertical hull projecting up into the water column. *Castine* has 6–10 ft (1.8–3.0 m) of vertical relief, and Site 323 projects 9–13 ft (2.7–4.0 m) above the seafloor. Both *Castine* and Site 323 were oriented nearly parallel with the direction of wave and current travel (see Figures 6 and 15). Their orientations and their relatively low vertical profile, with respect to the artificial reef vessels, might be a factor contributing to the relatively low damage experienced by these two study wrecks. *New York* and *Gulf Tide* are both substantially broken apart and/or buried and do not extend far into the water column (excluding the steam engine of *New York*), thus their orientations are less significant.

The possibility was also considered that intact hulls of shipwrecks might be reoriented by hurricane-induced waves to an alignment of least resistance, which might then result in less overall damage to intact shipwrecks than was the case for intentionally sunk artificial reef vessels. While this suggestion ignores the fact that artificial reef vessels should then also be reoriented if indeed this was occurring to shipwrecks, it was thought that perhaps a combination of factors might be at work. The BOEMRE wreck database was examined in order to determine whether the orientation of hulls on the seabed was biased toward certain compass directions in response to hurricane-induced bottom currents. The database was searched within UTM Zone 15N for shipwrecks for which hull orientation could be determined. A total of 30 were found. The frequency of hulls oriented along various compass directions has been plotted in 10-degree increments (Figure 49). The radial circles represent numbers of wrecks. The depth of these 30 shipwrecks ranges from 16.4 to 131.2 ft (5.0 to 40.0 m). Inspection of Hurricane Rita hindcast data suggests that the largest waves in these water depths tended to have the longest duration when traveling along headings ranging from 290 to 10 degrees.

From this sample of 30 shipwrecks reporting orientation data in UTM Zone 15N, exactly half were oriented with their long axis in the range of 290–10/100–190 degrees on the compass (see Figure 49), matching the travel direction of Rita's largest waves. The other half were oriented crosswise to the direction of Rita's largest waves along compass headings of 10–100/190–290 degrees. The direction of Rita's largest waves might not be typical of all hurricanes crossing UTM Zone 15N; nevertheless, there seems to be little evidence suggesting that hurricanes have played a role in determining the compass orientation of shipwrecks.

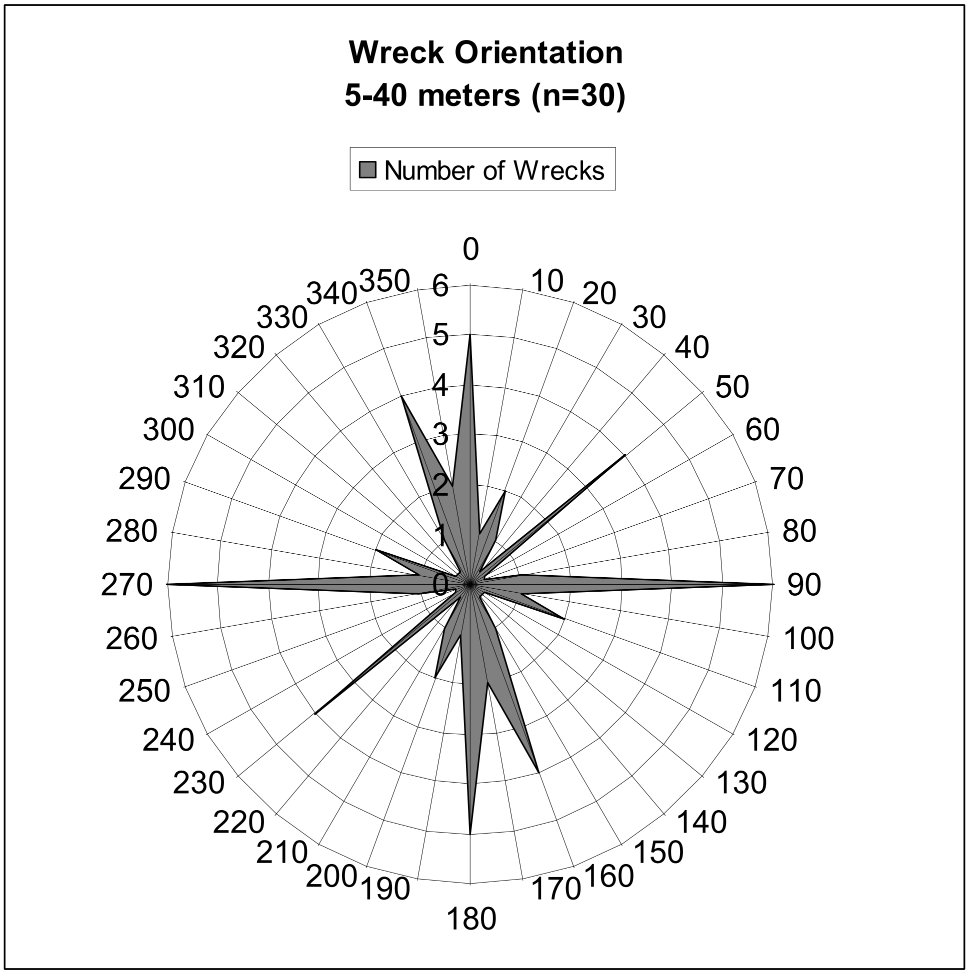


Figure 49. Compass orientation of shipwreck hulls from UTM Zone 15N.

4. Orientation along a vessel's roll axis is also relevant to the durability of a ship's hull. Vessels lying on the seabed in other than upright orientations might experience hull stresses along angles not intended by their designers, which could affect their structural integrity when subjected to hurricane waves. Such stresses might be exacerbated when the weight of an overturned hull is distributed unevenly upon a hard or irregular substrate. This could help explain the apparent new hurricane damage on Site 323 and at *Sheherazade* (see Appendix A), since both vessels are inverted. This does not, however, explain why the study wrecks experience less damage than the artificial reef vessels.

5. Age of a shipwreck (time since sinking) might actually play an important role in how much hurricane damage is sustained, but in a counterintuitive manner. Rather than susceptibility to damage increasing as a sunken vessel deteriorates with age, it appears possible that major hurricane damage is more likely when a shipwreck has only recently formed. The basis for this idea is the observation that extensive hurricane damage of the artificial reef vessels reported in Table 3 appears to have occurred when those sites experienced

their first hurricane. On the other hand, the four primary study sites have experienced many more hurricanes than any of the artificial reefs reported in Table 3 (see Appendix D), yet, by comparison, they had relatively minor damage resulting from Hurricanes Katrina and Rita.

Ships sunk as artificial reefs (from Table 3) were on the seafloor an average of only 6.7 years prior to being damaged by a hurricane. On average, hurricane-force wind gusts affect the coastal Florida counties for which artificial reef damage was reported once every 7.9 years (Klotzbach et al. 2010). A comparison of these two frequencies suggests that most reported damage must have been caused by the first hurricane to affect those artificial reef vessels. The primary study wrecks have been affected by hurricanes passing within 40 mi (64 km) on an average of once every 10 years (see Appendix D). Hurricane-force wind gusts affect the coastal Texas counties and Louisiana parishes between Galveston and New Orleans on average once every 10.3 years (Klotzbach et al. 2010). Those two frequencies agree quite well indicating that hurricane frequency at the study sites is typical of the larger region.

This study has determined that the magnitude of forces present at the four primary sites during peak storm conditions was comparable to the wind forces of an F3 to F5 tornado. Anything remaining unaffected by close passage of a hurricane must either be structurally strong enough to withstand that level of force or be sheltered from those forces by its position, orientation, or burial. Site 323 is the youngest of the four primary study sites (believed submerged for 20–35 years) and is the only site that exhibited obvious structural damage following Katrina and Rita (*Gulf Tide* lacked sufficient prestorm data to make a clear case either way). Depending upon the date when Site 323 sank (it was discovered in 1994), it might have experienced from one to three hurricanes. If it sank after 1985, then Rita would have been its first hurricane. By way of comparison, the other three primary sites experienced from 5 to 15 hurricanes within a 40-mi (64-km) radius.

The smaller number of hurricanes experienced by Site 323 as compared to the older study sites may be significant, because it is consistent with the authors' hypothesis that *major structural damage and movement tends to happen early in the life of a shipwreck as it settles toward a state of relative equilibrium with its environment.* In this model of site formation, scouring of the substrate by early storms would cause settlement of a hull to a depth beyond which further vertical displacement would require larger storm forces than previously experienced, assuming that the wreck has not encountered a harder substrate. Early lowering of a hull in this way, relative to the surrounding seafloor, would result in a more-stable position, less subject to rotational movements, as well as a lower vertical profile, thus reducing the surface area exposed to storm forces. The assumption is made that the most vulnerable areas of a hull are damaged early in the history of a shipwreck, leaving more-stable elements relatively undamaged by early storms until such time as chemical and biological weathering create new weaknesses that then become susceptible to damage by the next passing storm. Since chemical and biological processes may proceed at various rates, depending upon the nature and thickness of the material in question, hurricane damage of areas weakened by such processes might appear to be much more gradual, occurring over the course of several storms, than would be the case with a major catastrophic structural failure or movement of the hull caused by an early storm acting upon an unstable site.

5.3 Conclusion 3: Burial of Wooden Hulls has been Demonstrated, in the Case of *New York*, to Provide a High Degree of Protection from Hurricane Damage

On portions of the Continental Shelf where firm sediments prevent burial, exposed wood-hulled wrecks are presumed to deteriorate more completely due to biological activity, eventually becoming widely scattered by hurricanes and trawlers. The proportion of wood-hulled ships that wrecked in the GOM on a sufficiently firm seafloor so as to prevent their burial and in waters shallow enough to allow hurricane damage is unknown. However, a recent study of sediment shear strength in the GOM (Dunlap et al. 2004) provides one means for a rough estimate. The purpose of their study was to map areas where pipelines would self bury, negating the need for trenching. They determined that sediment shear strengths of <0.2 ksf at the seafloor would allow self burial of pipelines. McClelland Engineers (1979) classify sediments of this strength as "very soft." The area mapped by Dunlap et al. (Figure 50) included all GOM waters less than 328 ft (100 m) deep between the Mississippi-Alabama state line and a line about 50 mi (80.5 km) north of the Texas-Mexico border. This is approximately the same depth range likely to experience the effects of hurricanes. Sixty-five percent of that area (red color in Figure 50) was mapped as suitable for self-burial of pipelines.

Assume for the sake of discussion that sediments suitable for self burial of pipelines would also be sufficiently soft and thick enough to allow at least partial burial of wood-hulled shipwrecks, and that these shipwrecks are evenly distributed across the area mapped on Figure 50. In that case, the proportion of wood-hulled shipwrecks in the GOM exposed to the full force of hurricanes, wood borers, and trawl nets, might be on the order of 35 percent, corresponding to areas where sediments have shear strengths >0.2 ksf. The balance of wood-hulled shipwrecks in areas with sediment shear strengths <0.2 ksf (roughly 65 percent) would be buried and might be preserved as well as, or better than, *New York*. A separate study of correlations between sediment shear strength and shipwreck subsidence (Keith and Evans 2009) shows that shipwrecks can achieve significant burial in areas of sediment shear strength <0.6 ksf. These results imply that the proportion of buried and preserved wood-hulled wrecks in the GOM might exceed the 65 percent calculation based on the Dunlap et al. (2004) maps. While it is unlikely that wood-hulled shipwrecks are evenly distributed over the area mapped in Figure 50, this exercise provides a rough order-of-magnitude estimate.

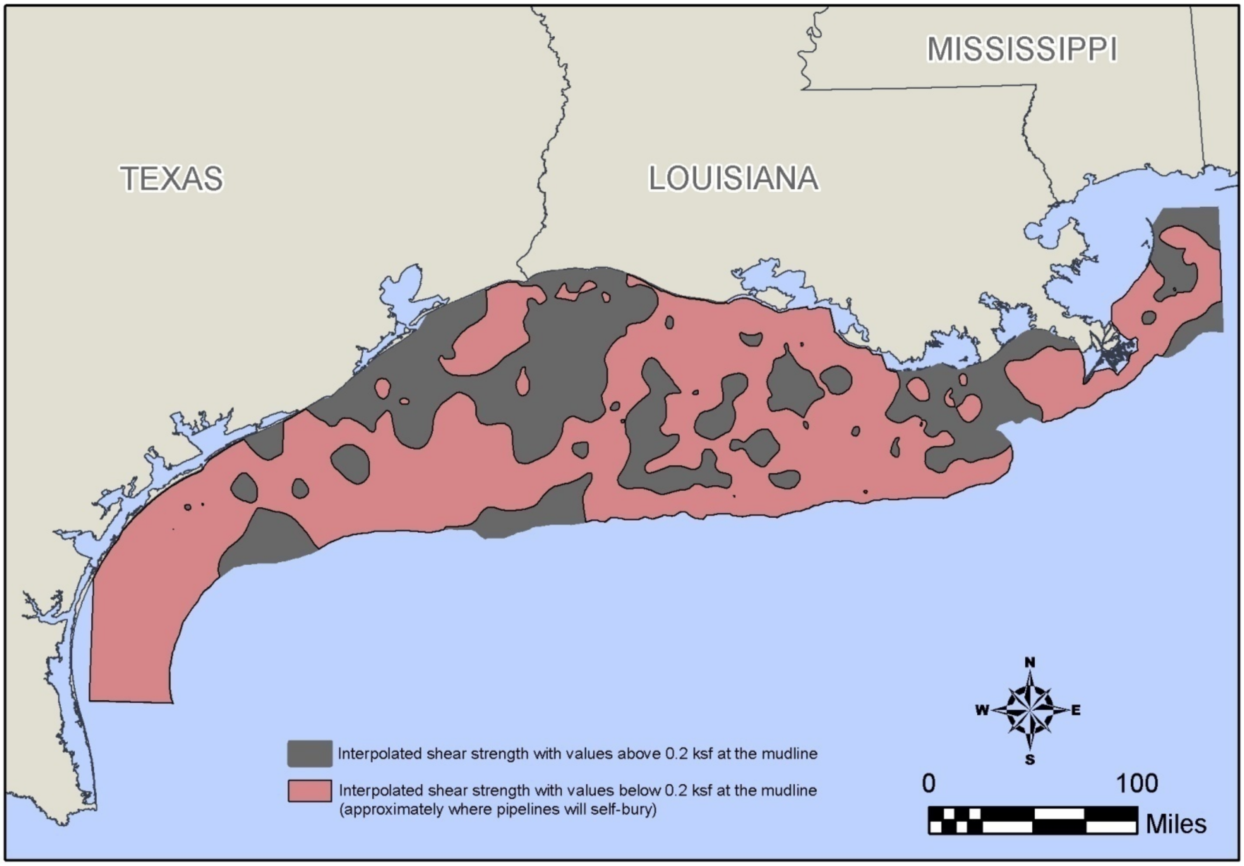


Figure 50. Shear strength of sediments in waters of the western Gulf of Mexico less than 328 ft (100 m) deep (based on GIS data from Dunlap et al. 2004).

Unfortunately for archaeologists, burial of wood-hulled shipwrecks in the shallow GOM makes them difficult to discover. The visibility and relatively intact nature of most metal hulls is their most notable characteristic. Wood hulls, on the other hand, generally are preserved only to some level below their water line, and what remains is typically hidden from view beneath sediment. Over time, exposed wood becomes riddled with holes from wood-boring mollusks and substantially weakened. Any wood remaining exposed after a few years is at increased risk of damage or removal by storms and trawl nets rendering most wood-hulled sailing ships in shallow waters unrecognizable to or even invisible to sonar surveys. This is clearly demonstrated by the fact that federally mandated oil and gas surveys have not confirmed a single example of a wood-hulled sailing shipwreck in GOM areas less than 656 ft (200 m) deep. While this lack of discovery can be partially explained by the enforcement of BOEMRE's avoidance criteria for unidentified sonar and magnetic targets, these targets are, by definition, unidentifiable as shipwrecks based on remote-sensing data alone. By contrast, at least five wood-hulled shipwrecks have been discovered in the GOM in waters deeper than 656 ft (200 m), where burial and biological decay occur slowly and the effects of hurricanes and trawlers does not come into play. To put this into perspective, at the time of this writing 98.3 percent of all active platforms and 89.2 percent of all approved applications to drill were located in waters less than 656 ft (200 m) deep (USDOI, Minerals Management Service 2010). Yet the substantially smaller amount of archaeological exploration required to permit the remaining 10.8 percent of approved drilling applications and 1.7 percent of active platforms in waters deeper than 656 ft (200 m) has accounted for 100 percent of the confirmed wood-hulled sailing ship discoveries resulting from BOEMRE-mandated surveys.

5.4 Conclusion 4: Anthropogenic damage to shipwrecks may be caused directly by human action or indirectly by hurricanes acting upon manmade structures.

One of the stated study objectives was to differentiate between natural (hurricane) and anthropogenic damage to shipwrecks based upon an understanding of hurricane impacts. Anthropogenic damage refers to that caused by human activity. Such damage may be caused either directly by human action, or indirectly by hurricane forces dragging a manmade structure across a shipwreck site. Anthropogenic damage to shipwrecks in the GOM is primarily associated with the commercial fishing and petroleum industries. Direct damage to shipwrecks by commercial fishing is due mainly to snagging of wreckage by trawl nets. Anthropogenic damage associated with the petroleum industry can occur in several ways, all of which involve manmade structures such as anchors, anchor chains, platform legs, pipeline ploughs, riser pipes, or pipelines coming into contact with a shipwreck. BOEMRE archeological regulations are designed to prevent inadvertent damage to shipwrecks by the petroleum industry; however, the potential for damage remains if BOEMRE procedures or avoidance recommendations are not honored, or if a hurricane causes a manmade structure to come in contact with a shipwreck.

Direct or indirect (hurricane-induced) anthropogenic damage to shipwrecks should be consistent with the size of the manmade object impacting a site. The direction of force causing the damage should also be evident unless the affected material is completely removed from the site (e.g., by trawl nets). Damage associated with the petroleum industry may occur at any depth where manmade structures touch the seafloor. Such damage may emanate from a single point on a wreck or extend across an entire site, depending upon the source of damage. For example, damage from an anchor, rig leg, or pipeline plough should emanate from the original point of contact with the shipwreck in the direction of the foreign object's movement.

An object dragging across a wreck might cut through a section of hull in a localized area or damage an entire site, depending on the size and orientation of the object. For example, linear manmade structures oriented parallel with the seafloor, such as pipelines or heavy anchor chains associated with floating platforms or pipe laying barges, can damage the entire breadth of a shipwreck site. Pipelines and anchor chains may drag across shipwreck sites during hurricanes, especially when floating platforms are moved laterally by a storm. Studies of pipeline damage following recent hurricanes in the GOM showed that "The majority of pipeline damages occurred at or near platform interfaces, in areas of mudflows, or as a result of impact by an outside force other than the hurricane, such as platform failures or dragged anchors" (DNV 2006:62). Damage caused by dragging a pipeline or anchor chain across a wreck might resemble the removal of superstructure commonly reported for artificial reef vessels following hurricanes.

Anthropogenic damage to shipwrecks from the GOM commercial fishing industry is primarily caused by hanging trawl nets on wreckage. Trawling in the GOM began around 1915 and was Gulf-wide by 1950 (Shapiro 1971 and Sheridan 2001, both cited in Committee on Ecosystem Effects of Fishing 2002). Today trawling occurs out to a depth of 50 fathoms (300 ft [91 m]), although the vast majority occurs between the coast and depths of 30 fathoms (180 ft [55 m]). The National Academy of

Sciences published a study regarding the effects of bottom trawling and dredge fishing techniques on seafloor habitat (Committee on Ecosystem Effects of Fishing 2002), which is equally relevant to historic preservation. Their study estimated that the total area fished in the GOM, reported as 104,128 square miles (269,690 km^2), was on average completely swept (e.g., Figure 51) over two and a half times during a single year of fishing. Localized areas were reportedly swept 37 to 75 times per year. Given the scope of the trawl fishing industry in the GOM it is difficult to imagine any exposed shipwreck remaining unaffected.

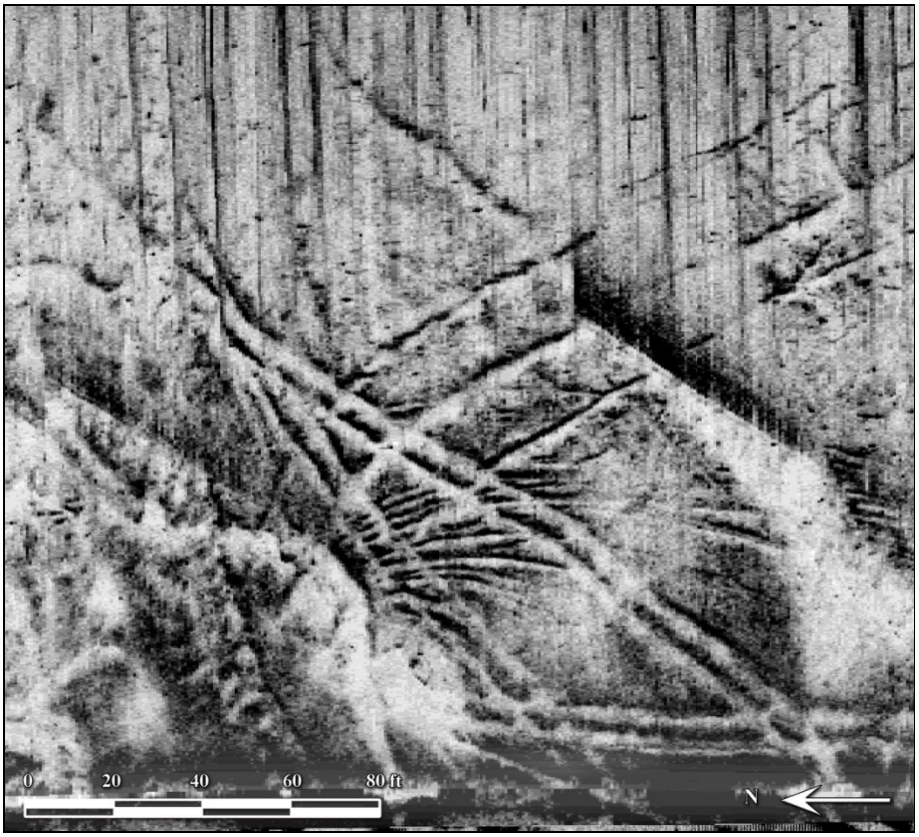


Figure 51. Sonar image of trawler scars on the seabed.

The effect of trawling on a shipwreck depends upon the nature of the site. In the case of intact metal hulls, nets are often lost on the sites, creating a diving hazard but doing relatively little damage. Conversely, exposed portions of wooden hulls in the shallow GOM tend to be substantially weakened by wood-boring organisms, so when nets snag they break off and displace exposed structure and artifacts, occasionally bringing them to the surface. This is a common way that historic sites come to the attention of treasure salvers, so in a sense salvage is also an indirect anthropogenic effect of commercial fishing practices. Once net hangs are known to fishermen, they also tend to become dumping sites for unwanted material, some of which is snagged elsewhere and then redeposited at a "safe" location (on a known hang) where it will not be snagged again on a later fishing trip. Redistribution of artifacts is not only damaging to shipwrecks from which they are removed; the practice also may lead to confusion about the age and cultural affiliation of sites if historic artifacts are transferred from one site to another.

Hurricane damage of shipwrecks is not likely to occur below a depth of 300 ft (91 m), except where movement of a floating platform drags anchors or a pipeline across the seafloor. In waters shallower than 300 ft (91 m), direct storm damage from wave and current forces may affect entire shipwreck sites, because such forces are not localized events. This is evident in many artificial reef vessels, for which common examples of site-wide damage include lateral and vertical displacement, structural failure, and rolling. Hurricane damage can, however, mimic localized drag damage emanating from a point source, as demonstrated at Site 323 (see Figure 30) and *Sheherazade* (Figure A-4). Although the damage at Site 323 superficially resembled a localized impact from a foreign object, the resulting hull fracture lacked evidence of a predominant force direction, indicating that damage was not due to directional dragging of an object across the hull. A similar effect was recorded in the sonar data for *Sheherazade*, though the site was not reexamined by divers following Hurricane Katrina.

5.5 Recommendations

The following recommendations are intended to apply the lessons learned from this study to future research and management of submerged cultural resources on the GOM OCS. "Adaptive management incorporates research into conservation action. Specifically, it is the integration of design, management, and monitoring to systematically test assumptions in order to adapt and learn" (Salafsky et al. 2001). The most useful lessons learned in this study, from a management standpoint, are (1) that hurricanes have the potential to indirectly cause anthropogenic damage to shipwrecks in the vicinity of pipelines or surface installations, and (2) that once a wood-hulled shipwreck becomes buried, it can potentially survive the passage of multiple severe hurricanes with little or no additional damage, as witnessed by the condition of *New York*. When incorporating these lessons into the larger goal of adaptive management, several recommendations for the research and management of shipwrecks in the GOM become clear.

5.5.1 Research Recommendations

The design of future hurricane damage studies should consider several questions. For example, does storm damage decrease in magnitude as shipwrecks age, as hypothesized above? How does vessel orientation affect storm damage? And, what effect do storms have on metal hulls that have exhibited significant prestorm corrosion? The discovery of additional wood-hulled shipwrecks in a variety of sediment types would also add greatly to our understanding of their long-term preservation in an environment dominated by frequent hurricanes. This last topic is perhaps the most important of all. Very few examples of wood-hulled shipwrecks have been discovered in the GOM, yet this group of shipwrecks has potential to contribute greatly to the knowledge base of pre-twentieth-century North American maritime history.

Site-specific sediment analysis should incorporate a combination of coring and shear strength measurements. Characterization of sediment bed formations at shipwreck sites is of clear value; however, the interpretive value of those data can be limited without corresponding site-specific shear strength data. Broad studies of shear strengths throughout the entire GOM provide a useful baseline data set, but they have limitations when used for analysis of archaeological site formation processes. Such studies are often compromised by widely spaced data nodes that are incapable of quantifying the unique characteristics at individual sites. Future BOEMRE studies of shipwrecks on the GOM shelf that require a sedimentology component should incorporate localized shear strength testing into the project scope. The most effective and economical method for achieving this would be by using a diver-held shear vane apparatus, or similar device. Furthermore, the authors recommend the use of low-tech, diver-controlled coring devices in place of box cores. Box cores, whether diver-held or deployed from the surface, are unwieldy and expensive to construct, and provide no tangible analytical benefit over lower-tech devices, such as a PVC pipe hammered into the substrate. In fact, the coring results from *New York* show that lower-tech collection methods may be more successful in achieving greater core depths compared to the relatively shallow box cores. These greater core depths are relevant when attempting to characterize sediments at and below the depth of subsidence at a shipwreck site.

5.5.2 Management Recommendations

Consider additional site protection measures in the vicinity of pipelines, cables, and standing or anchored structures. Sites are at elevated risk of indirect hurricane damage when located near any offshore structure or activity that touches the seafloor. If potential sites can be successfully identified prior to construction, they can be avoided to prevent damage in the event of a hurricane. Reports of hurricane damage to petroleum industry infrastructure in the GOM can be used as the basis for designing extra protection measures. For example, how far do pipelines move, in what direction, and under what circumstances? When a platform is moved by a hurricane, what length of pipe might it drag along the bottom as it moves? If pipes or platforms are at risk of movement, consideration should be given to surveying a wider area to locate potential shipwrecks in their vicinity.

In waters less than 300 ft (91 m) deep, survey line interval should be sufficiently narrow in the vicinity of bottom structures and anchor locations to ensure the discovery of buried wood-hulled shipwrecks on the basis of magnetic data. A maximum line interval of 66 ft (20 m) would be appropriate in such areas (Gearhart 2011). Such a requirement should apply at least to waters less than 300 ft (91 m) deep, where the combined effects of wood borers, hurricanes and trawling would be expected to remove the most visible portions of wood-hulled shipwrecks.

Between 300 ft (91 m) and 650 ft (198 m), both magnetometer and side-scan sonar should continue to be employed for archaeological surveys. Below 300 ft (91 m) deterioration of wooden hulls should be mostly biological. Burial should be limited predominantly to settlement due to a ship's weight combined perhaps with some deposition from distant alluvial sources. Remnants of wooden hulls might no longer be visible above 650 ft (198 m) due to biological activity; however, one might observe non-perishable elements of wood-hulled shipwrecks in situ on side-scan sonar.

In waters less than 650 ft (198 m) deep but greater than 100 ft (30 m), for survey line intervals of 100 ft (30 m) or less, consideration should be given to improving the accuracy of horizontal positioning for magnetometer sensors. In the absence of a sonar target, any hope of differentiating a potential shipwreck anomaly from debris (Gearhart 2011) depends upon accurate horizontal positioning for the magnetometer sensor. Sonar targets of wood-hulled sailing shipwrecks in these water depths are presumed to be difficult to recognize and perhaps often non-existent, since none have yet been confirmed from federally-mandated surveys. When survey line intervals exceed 100 ft (30 m), the positioning accuracy for a magnetometer sensor is less of an issue, as there is a low expectation that anomalies on adjacent survey lines would be associated with a single wood-hulled shipwreck. However, if a survey is conducted using a line interval of 100 ft (30 m) or less, then it becomes important that the positions of magnetic field measurements on adjacent survey lines be mapped accurately with respect to neighboring values.

Improvements in underwater positioning accuracy are possible using an Autonomous Underwater Vehicle (AUV) equipped with an inertial guidance system. The level of accuracy achievable with an inertial system is superior to acoustic positioning of deep-towed sensors and allows more realistic mapping of magnetic anomalies, which in turn allows more accurate interpretation of their potential association with shipwrecks. AUVs can be programmed for close-order survey of magnetic anomalies and sonar targets, providing a means of prioritizing targets and eliminating some targets from further consideration. They are also capable of providing photography that could aid in interpretation of sonar targets. AUV technology continues to improve rapidly and is now available at a size that can be deployed from a small survey vessel with a crew of two persons. Small systems are now available at a cost that is competitive with rates for a traditional towed survey spread. The authors recommend promoting the use of AUVs, equipped with inertial guidance, side-scan sonar, magnetometer, and a downward-looking camera, for archaeological surveys.

6.0 LITERATURE CITED

Alden, J.D. (Commander). 1972. The American steel navy. Annapolis, Maryland: Naval Institute Press.

Anonymous. 1925. Historical sketch of the U.S.S. *Castine*. Naval Historical Center, Ships History Files, Washington, DC.

Barton, J.K. and R.G. Denig. 1893. The contract trials of the U.S. gunboats *Machias* and *Castine*. Journal of the American Society of Naval Engineers 4.

Baughman, J.P. 1968. Charles Morgan and the development of southern transportation. Nashville, TN: Vanderbilt University Press.

Beavers, R.L. 1999. Storm sedimentation on the surf zone and Inner Continental Shelf, Duck, North Carolina. Ph.D. Dissertation, Department of Geology, Duke University, Durham, NC.

Bell, M. and J.W. Hall. 1994. Effects of Hurricane Hugo on South Carolina's marine artificial reefs. Bulletin of Marine Science 55(2-3):836–847.

Berryhill, H.L., Jr. 1984. Distribution and thickness of Holocene sediments. Shallow geology of the Continental Shelf and Upper Continental Slope. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Map Series MMS 84-0003. Sheet VI.

Berryhill, H.L., Jr. and D.E. Owen. 1984. Location of diapirs, fold axes, and faults. Shallow geology of the Continental Shelf and Upper Continental Slope. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Map Series MMS 84-0003. Sheet III.

Berryhill, H.L., Jr., D.E. Owen, and J.R. Suter. 1984. Distribution of ancient fluvial sediments of probable early and late Wisconsinan age. Shallow geology of the Continental Shelf and Upper Continental Slope. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Map Series MMS 84-0003. Sheet II.

Biesele, R.L. 1930. The San Saba Colonization Company. Southwestern Historical Quarterly 33:3.

Big Spring [Texas] *Daily Herald*. 1969. "Liberian ship lost in Gulf, crew of 34." March 16, No. 245.

Blair, S.M., T.L. McIntosh, and B. Mostkoff. 1994. Impacts of Hurricane Hugo on the offshore reef systems of central and northern Dade County, Florida. Bulletin of Marine Science 54(3):961–973.

Bloomfield, L. 2008. Email communication to Doug Jones, PBS&J, Austin, Texas, March 18.

BoatInfo World. 2009. Boat, yacht, & ship information center. Internet website: http://www.boatinfoworld.com/. October.

Bullock, F.J. (Ensign). 2008. Email from U.S. Coast Guard Sector New Orleans to Doug Jones, March 24.

Bureau of Aeronautics. 1943. “Dredging river front for crash boat at NAS Charleston, S.C.” Photograph taken June 15, 1943. Negative No. 214361. National Archives and Records Administration, College Park, MD.

Bureau of Construction and Repair. n.d.a. Ships History Files, decommissioned (Prior to 2001) CASINGHEAD (YO47) TO CATALPA (AN 10), Box 165, Ships History Branch, Naval Warfare Division, Naval Historical Center, Washington, DC.

———. n.d.b. “Ship’s information, USS *Castine.*” Ships History Files, Ships History Branch, Naval Warfare Division, Naval Historical Center, Washington, DC.

Chaplin, J.R. 1999. CW263 – One stop code for non-linear regular waves on a uniform current by stream function theory. School of Civil Engineering and the Environment, University of Southampton, Southampton, United Kingdom.

Civilian and Gazette, The (Galveston, Texas). 1838. January 11, 1838. Vol. 1, No. 15.

———. 1843. February 8, 1843.

———. 1845. December 10, 1845.

———. 1846. Loss of the steamship *New York*: afflicting loss of life. September 10, 1846.

Colton, T. 2009. Home Page. internet website: http://www.ShipbuildingHistory.com/. October 1.

Commander, Cruiser Force. 1916. “Confidential order to Commanding Officer, USS *Castine*, 21 August 1916.” National Archives and Records Administration. Record Group 45: Navy Subject File 1910-1927. USS *Castine*, Box 1056. Washington, DC.

Commander, Cruiser Squadron. 1916a. “Movement orders for USS *Castine*, 27 February 1916.” National Archives and Records Administration. Record Group 45: Navy Subject File 1910-1927. USS *Castine*, Box 1056. Washington, DC.

———. 1916b. “Movement orders for USS *Castine*, 24 May 1916.” National Archives and Records Administration. Record Group 45: Navy Subject File 1910-1927. USS *Castine*, Box 1056. Washington, DC.

Committee on Ecosystem Effects of Fishing, National Research Council. 2002. Phase 1 – effects of trawling and dredging on seafloor habitats. National Academy Press, Washington, DC.

Coombe, P.W. 1986. James P. Allaire – marine engine builder. Steamboat Bill, Journal of the Steamship Historical Society of America XLIII, No. 3:263-271.

Courier (London), *The*. 1837. Loss of the steam packet home and from eighty to ninety lives. 15 November, p. 1.

Daily Picayune [New Orleans]. 1846. September 10.

Dalrymple, R.A. 1974. “A finite amplitude wave on linear shear current.” Journal of Geophysical Research 79(30):4498–4504.

Dean, R.G. 1965. Stream function representation of nonlinear ocean waves. Journal of Geophysical Research 70(18):4561–4572.

Det Norske Veritas (DNV). 2006. Pipeline damage assessment from Hurricane Ivan in the Gulf of Mexico. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico Region. Report No. 440 38570, Revision No. 2.

———. 2007. Pipeline damage assessments from hurricanes Katrina and Rita in the Gulf of Mexico. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico Region, Report No. 448 14183, Revision No. 1.

Dunlap, W., L. Holcombe, and T. Holcombe. 2004. Shear strength maps of shallow sediments in the Gulf of Mexico. Final report prepared for the U.S. Dept. of the Interior, Minerals Management Service, under MMS/OTRC Cooperative Agreement 1435-01-99-CA-31003, Task Order 17007, Project 367. College Station, TX: Offshore Technology Research Center, Texas A&M University.

El Paso [Texas] *Herald-Post*. 1977. "Davy's locker gets 'El Paso'." December 9.

Enright, J.M., R. Gearhart II, D. Jones, and J. Enright. 2006. Study to conduct National Register of Historic Places evaluations of submerged sites on the Gulf of Mexico Outer Continental Shelf. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA.

Floyd, R.J. 2001. Email communication to David Ball at Minerals Management Service. February 23, 2001.

Fugro Geoservices, Inc. 2001. Archeological and shallow hazard report, Block A-9, OCS-G-09093, High Island Area, Gulf of Mexico. Report No. 2401-1221. Prepared for Cronus Offshore, Inc. Lafayette, LA.

Galveston Daily News. 1947. "Sunken dredge." September 30.

———. 1975. "Crewman's bodies believed located." December 27, p. 2A.

———. 1983. "Divers find survivor on sunken crew boat." November 12, p. 1.

Gearhart, R. 2007a. May 2007 geophysical survey trip report: impacts of recent hurricane activity on historic shipwrecks in the Gulf of Mexico. Submitted to U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. July 9.

———. 2007b. Avoiding buried shipwrecks in offshore sands: a methodology for interpretation of magnetic anomalies. Presentation at the American Shore & Beach Preservation Association/General Land Office Fall Coastal Conference. Caring for the Coast: Protecting, Enhancing, Preserving. Galveston, Texas. October 24.

———. 2011. Archaeological interpretations of marine magnetic data. In: Hamilton, D.M., B. Ford, and A. Catsambis, eds. The Oxford Handbook of Maritime Archaeology, pp. 90–113. Oxford, England: Oxford University Press. In publication.

Geotex Company. 2006. A high-resolution geophysical survey report of East Cameron area block 115, OCS-G-27825, Offshore Louisiana – Gulf of Mexico. Prepared for Remington Oil and Gas Corporation.

Goodspeed Publishing Company. 1892. Biographical and historical memoirs of Louisiana, Vol. 2. Chicago: Goodspeed Publishing Company.

Gregg, K. and S. Murphey. 1994. The role of vessels as artificial reef material on the Atlantic and Gulf of Mexico coast of the United States. Special Report No. 38 of the Atlantic States Marine Fisheries Commission.

Gulf States Marine Fisheries Commission. 2008. Home Page. Internet website: http://www.gsmfc.org. April 2008.

Halpern, P.G. 1994. A naval history of World War I. Annapolis, Maryland: Naval Institute Press.

Havern, C.B. 2008. Letter from U.S. Coast Guard Commandant, Office of Information Resources, to Douglas Jones, PBS&J, Austin, Texas. FOIA Request 2008-1049.

Haworth, R.B. 2009. Miramar ship index. Internet website: http://www.miramarshipindex.org.nz/. October.

Hebert, G. 2008. Email to Doug Jones, PBS&J, Austin, Texas. December 11.

Herbich, J.B. 2000. Handbook of dredging engineering. New York: McGraw-Hill.

Heyl, E. 1953. Early American steamers. Self published, Buffalo, NY.

Holley, M.A. 1933. Letter to Mrs. William M. Brand, November 1840. Excerpt reprinted in *Mary Austin Holley* by Mattie Austin Hatcher. Dallas, TX: Southwest Press, Inc.

Holly, D.C. 1995. Recovery of the crosshead engine from the steamboat *Columbus*. Steamboat Bill, Journal of the Steamship Historical Society of America LII(1):40-46.

Horn, W.M. 2005a. Preliminary report of the impacts to Florida's artificial reefs from four major hurricane landfalls during the summer and early fall of 2004. Proceedings of the Eighth International Conference on Artificial Reefs and Artificial Habitats (CARAH), April 10, 2005–April 14, 2005, Biloxi, Mississippi.

———. 2005b. Dive assessment of the ex-USS *Spiegel Grove* artificial reef located offshore Key Largo, Monroe County, Florida, July 24. Florida Fish and Wildlife Conservation Commission, Division of Marine Fisheries Management, Artificial Reef Program.

Horn, W.M. and K. Mille. 2005. Post hurricane dive assessment of artificial reefs south of Destin, Florida, May 19. Florida Fish and Wildlife Conservation Commission field report.

Irion, J.B. and R.K. Anderson, Jr. 1995. Archaeological investigations of the steamboat *Columbus* (18ST625) in Chesapeake Bay, Maryland: its history, architecture, and crosshead steam engine. In Underwater Archaeology Proceedings from the Society for Historical Archaeology Conference. Johnston, Paul Forsythe, ed. Washington, DC: Society for Historical Archaeology.

Irion, J.B. and R.J. Anuskiewicz. 1999. MMS seafloor monitoring project: first annual technical report, 1997 field season. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA.

Irion, J.B. and D.A. Ball. 2001. The *New York* and the *Josephine*: two steamships of the Charles Morgan Line. The International Journal of Nautical Archaeology 30.1:48–56.

Jones, D. 2007. Too much top for its bottom: the historical and archaeological identification of the USS *Castine* and the significance of U.S. gunboats in the early steel navy. M.S. Thesis, East Carolina University, Greenville, NC. 162 pp.

———. 2008. Letter to Ensign F.J. Bullock, Assistant FOIA Officer, U.S. Coast Guard Sector New Orleans. March 26.

Jordan, J. 2006. Lone Star Navy: Texas, the fight for the Gulf of Mexico, and the shaping of the American west. Washington, DC.: Potomac Books, Inc.

Keith, M.E. and A.M. Evans. 2009. Shipwreck subsidence; Applying geotechnical concepts in archaeology. In: ACUA Underwater Archaeology Proceedings 2009. Laanela, E. and Jonathan Moore, eds. An Advisory Council on Underwater Archaeology Publication.

Kiter, T.L. 2008. Email from New York Historical Society, Manuscripts Department, to Doug Jones, PBS&J, Austin, Texas. February 22.

Klotzbach, P., W. Gray, U. Shama, and L. Harman. 2010. United States landfall probability webpage. Colorado State University with assistance from GeoGraphics Laboratory, Bridgewater State College. Internet website: http://www.e-transit.org/hurricane/welcome.html. March 25.

Knox, D.W. (Capt.). 2003. American naval participation in the Great War (with special reference to the European Theater of Operations). Hearings before Committee on Naval Affairs of the House of Representatives on Sundry Legislation Affecting the Naval Establishment, 1927-1928. U.S. Congress. House Committee on Naval Affairs. 70th Cong., 1st Session. Internet website: http://www.history.navy.mil/library/special/american_naval_part_great_war.htm. July 6, 2005.

Landsea, C.W., J.L. Franklin, C.J. McAdie, J.L. Beven II, J.M. Gross, B.R. Jarvinen, R.J. Pasch, E.N. Rappaport, J.P. Dunion, and P.P. Dodge. 2004. A reanalysis of Hurricane Andrew's intensity. American Meteorological Society, Boston, MA.

Leahy, W.D. 1897–1931. "Leahy diary, 1897–1931." Unpublished MS submitted to Wisconsin Historical Society, Madison.

Ledet, D.P. 2008. Email from Chief, Marine Information Section, U.S. Coast Guard, to Doug Jones, PBS&J, Austin, Texas. March 25.

———. 2009. Email from Chief, Marine Information Section, U.S. Coast Guard, to Doug Jones, PBS&J, Austin, Texas. October 14.

Lewis Publishing Company. 1895. History of Texas, together with a biographical history of the cities of Houston and Galveston. Chicago: Lewis Publishing Company.

Lochhead, J.L. 1954. Disasters to American vessels, sail and steam, 1841–1846. Compiled from the New York Shipping and Commercial List. Mariners' Museum, Newport News, VA.

Lukens, R.R. and C. Selberg. 2004. Guidelines for marine artificial reef materials. 2nd ed. Artificial Reef Subcommittees of the Atlantic and Gulf States Marine Fisheries Commissions.

Lytle, W.M. and F.R. Holdcamper. 1975. Merchant steam vessels of the United States, 1790–1868. The Steamship Historical Society of America, Inc., Staten Island, NY.

Maher, T. 1996. OFMAS artificial reef assessment dive team reef evaluation dives, Escambia County, August 6 and 7, 1996. Florida Department of Environmental Protection field report. 9 pp.

Malsch, B. 1978. Indianola: the mother of Western Texas. 3rd ed. Austin, TX: Shoal Creek Publishing.

Manchester [England] *Examiner, The.* 1846. Interesting shipwreck narrative. 24 October 1846.

Mandke, J.S., Y.T. Wu, and R.S. Marlow. 1995. Evaluation of hurricane-induced damage to offshore pipelines. Final report prepared for the U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico Region (Contract 14-35-0001-30748) by Southwest Research Institute, San Antonio, TX.

Martin, B. 2008. Letter from U.S. Coast Guard, Data Management & Administration Division to Doug Jones, PBS&J, Austin, Texas. FOIA Request 08-0569. March 4.

McClelland Engineers. 1979. Strength characteristics of near seafloor continental shelf deposits of North Central Gulf of Mexico. Houston, TX.

Means, R.E. and J.V. Parcher. 1963. Physical properties of soils. Columbus, OH: Charles E. Merrill.

Morelock, J. and W.R. Bryant. 1972. Consolidation of marine sediments. In: Rezak, R. and V.J. Henry, eds. Contributions on the geological and geophysical oceanography of the Gulf of Mexico, Vol. 3. Texas A&M University Oceanographic Studies. Houston, TX: Gulf Publishing Company. Pp. 181–202.

Morrison, J.H. 1903. History of American steam navigation. New York: W.F. Sametz & Co., Inc.

———. 1909. History of the Port of New York yards. New York: Wm. F. Sametz & Co. The Michigan Historical Reprint Series. The Scholarly Publishing Office, The University of Michigan University Library.

Naval History and Heritage Command. 2010. Online library of selected images. USS *Castine* (Gunboat #6), 1894–1921. Photo #NH2087. Internet website: http://www.history.navy.mil/ photos/images/ h02000/h02087.jpg. March.

Newark [OH] *Daily Advocate.* 1898. "Castine's capture." May 3, 1898.

New Orleans Bee. 1839a. January 25, 1839.

———. 1839b. Marine Intelligence. February 2, 1839.

———. 1846. Loss of the Steamship New York. 10 September 1846. P. 1.

New Orleans Item. 1924. "Old fighting ship springs leak and goes down in Gulf," December 13.

New York Herald. 1846a. "Loss of Steamer New York." September 17.

———. 1846b. No title. Reprinted from September 11 edition, *New Orleans Picayune.* September 21.

New York Times. 1878. Obituary, Charles Morgan. 9 May. P. 4.

———. 1894. "The remedy in coal and water: how it is proposed to make stable the gunboats *Machias* and *Castine.* January 21.

———. 1895. "Article 4 – No title." January 12.

———. 1898. "Troops landed near Santiago." June 23.

———. 1899. "The surrender of Zamboanga." December 2.

———. 1900. “Spanish War prizes.” April 10, 1898.

Oceanweather, Inc. 2006. Hindcast data on winds, waves, and currents in Northern Gulf of Mexico in Hurricanes Katrina and Rita.

Officer, L.H. and S.H. Williamson. 2009. “Purchasing power of money in the United States from 1774 to 2010,” MeasuringWorth, 2009. Internet website: http://www.measuringworth.com/ppowerus/. March 2010.

Offshore Marine Service Association [OMSA]. 2010. Internet website: http://www.offshoremarine.org/About/OMSA-s-History.html. March 8.

Pemberton, W. 2005. Palm Beach County Reef Research Team. Hurricane damage photos. Internet website: http://www.pbcrrt.org/PBCRRT_HurricaneAssessment.shtml. January.

Pepper, A. 1957. “Allaire’s early industrial ‘kingdom’ to be restored.” The Royle Forum. December 15:8–11.

Playground Daily News [Fort Walton Beach, FL]. 1977. “Sinking inquiry goes on.” April 6, pg. B1.

Powell, M.D., and S.H. Houston. 1998. Surface wind fields of 1995 hurricanes Erin, Opal, Luis, Marilyn, and Roxanne at landfall. Monthly Weather Review 126:1259–1273. American Meteorological Society.

Racal, Inc. 1997. Title unknown. West Cameron 299 Lease Block Survey Report, prepared for I.P. Petroleum Company, Inc. Job No. 31158.

Ruston [LA] *Daily Leader.* 1975a. “No trace of oil crew found.” April 7, pg. 9.

———. 1975b. “Search called off for missing crewmen.” December 29, pg. 12.

Salafsky, N., R. Margoluis, and K. Redford. 2001. Adaptive management: a tool for conservation practitioners. Washington, DC: Biodiversity Support Program.

Shapiro, S. (ed.). 1971. Our changing fisheries. National Oceanic and Atmospheric Administration. U.S. Department of Commerce.

Sheridan, P.F. 2001. Pete Sheridan presentation notes. Presentation to the Committee on ecosystem effects of fishing: Phase 1 – effects of bottom trawling on seafloor habitat, Galveston, TX. March.

Steamboat Inspection Service. n.d. “Annual report of accidents investigated, 1911–1937. Vol. 15.” National Archives and Records Administration. Record Group 41: Records of the Bureau of Marine Inspection and Navigation, 1924.

Swanton, Henry A., Collection. 1994. Pictures taken and collected, 1895–1902: Bath Iron Works, Bath, Maine; Crescent Shipyard, Elizabethport, New Jersey; Maryland Steel Co., Sparrow’s Point, Maryland; Harlan & Hollingsworth, Wilmington, Delaware. Massachusetts Institute of Technology. On file at the Mariners’ Museum, Newport News, VA.

Toppan, A.C. 2002. Bath iron works. Portsmouth, NH: Arcadia Publishing.

Trabant, P.K. 1994. Shallow hazards study and cultural resources report of East Cameron Block 115 OCS-G-14361, Gulf of Mexico. Submitted to Apache Corporation.

Turpin, R.K. and S.A. Bortone. 2002. Pre- and post-hurricane assessment of artificial reefs: evidence for potential use as refugia in a fishery management strategy. ICES Journal of Marine Science 59:S74–S82.

U.S. Bureau of Customs. 1958–1967. Merchant vessels of the United States. Government Printing Office, Washington, DC.

U.S. Bureau of Ships. 1894. Ship Plan. "*Castine*, U.S. twin screw steel, Gun Boat No. 6, poop, forecastle and gun deck joiner plan." National Archives Record Group 19, Dash Series, Map 23-2-5. College Park, MD.

———. 1951a. YM-22 Machinery arrangement. Record Group 19, YM-22 Hull Series. National Archives and Records Administration, College Park, MD.

———. 1951b. YM-22 Machinery arrangement, plan of machinery deck, and elevation of dredge (prior to 1951 overhaul). Record Group 19, YM-22 Hull Series. National Archives and Records Administration, College Park, MD.

U.S. Dept. of the Army, Corps of Engineers (USACE). 1983. Engineering Manual EM-1110-2-5025. Manual approved for public release from Internet website: http://140.194.76.129/publications/eng-manuals/em1110-2-5025/toc.htm. Washington, DC. February 7, 2010.

U.S. Dept. of Commerce, Bureau of Navigation. n.d. "Master carpenter's certificate." National Archives and Records Administration. Record Group 26: Records of the U.S. Coast Guard, Vessel Documentation Files, 1923. Fort Worth, TX.

U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration (USDOC, NOAA). 2010. Historical hurricane tracks. Internet website: http://csc-s-maps-q.csc.noaa.gov/hurricanes/download.jsp. May 13.

U.S. Dept. of the Interior, Minerals Management Service (USDOI, MMS). 2010. Offshore Statistics by Water Depth. Internet website: http://www.gomr.mms.gov/homepg/fastfacts/WaterDepth/WaterDepth.html. May.

U.S. Dept. of the Interior, National Park Service (USDOI, NPS). 1985. Nominating historic vessels and shipwrecks to the National Register of Historic Places. National Register Bulletin 20. Interagency Resources Division, U.S. Dept. of the Interior, Washington, DC.

———. 1997. Guidelines for completing National Register of Historic Places forms. U.S. Department of the Interior, Washington, DC.

———. 2009. Determination of eligibility notification, USS *Castine.* Letter to Dr. M. Stright, Minerals Management Service, March 6, 2009.

U.S. Dept. of the Navy. 1898. Annual reports of the Secretary of the Navy. Washington, DC: Government Printing Office. Internet website: http://www.history.navy.mil/wars/spanam/sn98-1.htm. January 4, 2007.

U.S. Dept. of Transportation, Coast Guard. 1968–1989. Merchant vessels of the United States. Government Printing Office, Washington, DC.

U.S. District Court, Western District of Louisiana, Lafayette-Opelousas Division. 2006. Gentlemen of Fortune, LLC vs. the unidentified, shipwrecked vessel, her tackle, appurtenances, and cargo, in rem. Civil Action No. 06cv1495. Document 1-1.

———. 2007. Gentlemen of Fortune, LLC vs. the unidentified, shipwrecked vessel, her tackle, appurtenances, and cargo, in rem. Civil Action No. 06cv1495. Document 16.

U.S. Hydrographic Office. 1947a. Index to notices to mariners, nos. 27 to 52, inclusive. Notice to Mariners 41, October 11. Washington, DC.: U.S. Government Printing Office.

———. 1947b. Index to notices to mariners, Nos. 27 to 52, inclusive. Notice to Mariners 42, October 18. Washington, DC.: U.S. Government Printing Office.

U.S. Naval Historical Center. 2005. Loss of USS *Memphis,* 29 August 1916. Online Library of Selected Images. Internet website: http://www.history.navy.mil/photos/events/ev-1910s/ev-1916/ memphis.htm. March.

USS *Castine*. 1917. Deck logs. National Archives and Records Administration, Record Group 24: Records of the Bureau of Naval Personnel, Logs of Ships and Stations. Washington, DC.

Wang, R. and M. Manausa. 2005a. Hurricane Jeanne characteristics and storm tide evaluation. Prepared by Beaches and Shores Research Center, Institute of Science and Public Affairs, Florida State University, for Florida Department of Environmental Protection, Bureau of Beaches and Coastal Systems.

———. 2005b. Hurricane Frances characteristics and storm tide evaluation. Prepared by Beaches and Shores Research Center, Institute of Science and Public Affairs, Florida State University for Florida Department of Environmental Protection, Bureau of Beaches and Coastal Systems.

Williams, V. Leon. 1985. “The U.S. Navy in the Philippine insurrection and subsequent native unrest, 1898–1906.” Ph.D. dissertation, Department of History, Texas A&M University, College Station, TX.

Works Progress Administration. 1942. Ship registers and enrollments of New Orleans. Vol. 3 Louisiana State University, Baton Rouge.

Appendix A

Pre- and Posthurricane Remote-Sensing Data for Secondary Wreck Sites

APPENDIX A: PRE- AND POSTHURRICANE REMOTE-SENSING DATA FOR SECONDARY WRECK SITES

SITE 15306

Site 15306 is a modern wreck of unknown identity, located in the Vermillion lease block area. The site was first discovered by side-scan sonar during a lease block survey for Shell Deepwater Development Systems, Inc. and identified as "an oval shaped high density object" (Monier et al. 1998). A subsequent survey, for McMoRan Oil & Gas, LLC in preparation for laying a pipeline in the vicinity recorded a 72-foot (ft) (21.9-meter [m]) long sonar target with a corresponding magnetic anomaly at Site 15306 (el Darragi et al. 2001). The site was labeled as a shipwreck in the BOEMRE database.

In 2004 PBS&J performed a remote-sensing survey and diver investigation of Site 15306 as part of an NRHP evaluation of submerged sites in the Gulf of Mexico (Enright et al. 2006). That study recorded an upside-down, steel, V-hulled, twin-screw boat, with approximate dimensions of 65 x 15 ft (19.8 x 4.6 m), and at a depth of between 114 and 121 ft (34.7–36.9 m) (Figure A-1). A through-hull mount for an echo-sounder transducer confirmed that the wreck was modern. A search of the BOEMRE shipwreck database, the Automated Wreck and Obstruction Information System (AWOIS) maintained by the National Oceanic and Atmospheric Administration, and the Louisiana Division of Archaeology shipwreck database failed to locate any viable candidates for Site 15306's identity within a 20-mi (32.2-km) radius, and the site was deemed not eligible for listing in the National Register of Historic Places (NRHP) (Enright et al. 2006). The 2004 remote-sensing survey also recorded an oil well platform 550 ft (168 m) east of the shipwreck, a possible pipeline trench connecting to the platform and running approximately 360 ft (110 m) southeast of Site 15306, and four circular depressions within an area 40 ft (12.2 m) in diameter and 480 ft (146 m) northeast of the site. These depressions were speculated to be evidence of a temporary spud placement for the oil well, prior to the permanent mooring at its current location.

In 2005 Hurricane Rita passed 37.5 mi (60.4 kilometers [km]) west of Site 15306. The hindcast study for Hurricane Rita (Oceanweather, Inc. 2006) estimated a peak sustained wind speed over the site of 75 miles per hour (mph) (33.5 meters per second [m/s]) and a maximum significant wave height of 33.1 ft (10.1 m). PBS&J conducted a remote-sensing survey of the site on May 8, 2007. As with the 2004 survey, the magnetometer data were significantly skewed by the proximity of the oil well and pipeline. Magnetometer amplitudes over Site 15306 ranged from –340 to +345 gammas. The sonar imagery showed no noticeable change from the 2004 data. Hull orientation remained consistent, and there was no visible structural damage (see Figure A-1). There were also no visible or reported impacts to the nearby oil well and pipeline. The pipeline trench to the southeast of Site 15306 remained clearly visible, though no visual evidence remained of the circular spud-placement depressions recorded in the 2004 survey. According to the Geographic Information System (GIS) data on pipeline and platform damage, the closest reported pipeline damage to Site 15306 was a Newfield Exploration Company line pulled up 3.5 miles (mi) (5.6 km) to the southeast. No further diving investigation for hurricane impacts was recommended (Gearhart 2007).

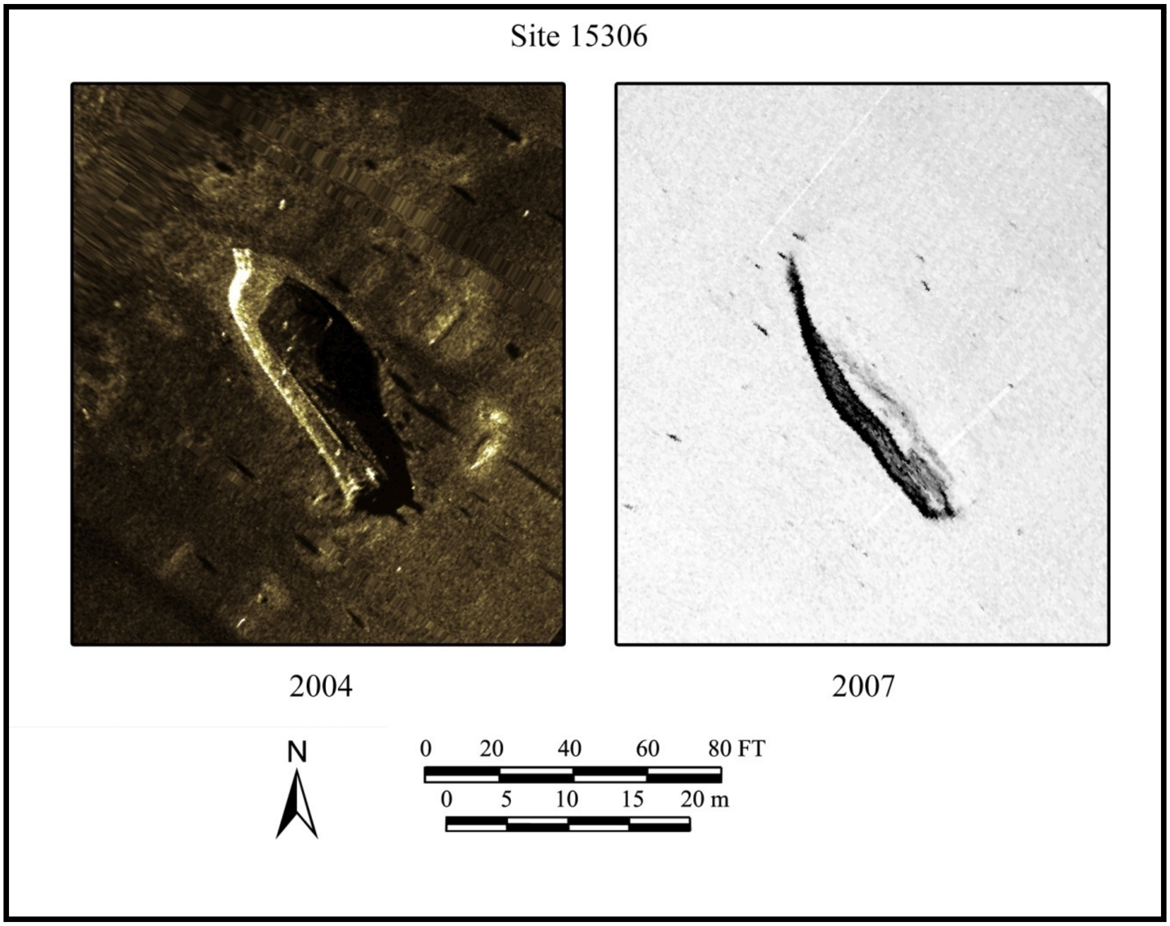


Figure A-1 Pre- and posthurricane sonar imagery of Site 15306.

SHEHERAZADE

SS *Sheherazade* (BOEMRE vessel ID 328) is located in the Eugene Island lease block area, 82.9 mi (133.3 km) east of Hurricane Rita's path. *Sheherazade* was a French-built petroleum tanker, launched in 1935 (Figure A-2). The massive ship measured 574 ft (175.0 m) long by 72 ft (21.9 m) abeam with a 31-ft (9.4-m) draft, and at 18,530 tons was the largest tanker in the world prior to World War II (*Dothan Eagle* 1950). In the late 1930s and into 1941, *Sheherazade* was chartered to bring petroleum products from America to French North Africa, until a commercial shipping crisis resulting from German U-boat attacks spurred President Franklin Roosevelt to seize foreign ships lying idle in U.S. ports (American Merchant Marine at War 1998). The U.S. War Shipping Administration (WSA) requisitioned *Sheherazade* from France in February 1942 and commenced chartering the tanker to American shipping companies for fuel and heating oil transport along the Gulf and eastern coastlines (U.S. Coast Guard [USCG] 1942). On June 11, 1942, *Sheherazade* was en route to Houston when it was torpedoed three times by U-*158*, 20 mi (32.2 km) west of Ship Shoal.

Figure A-2 SS *Sheherazade.*

Site 328 was initially recorded in a 1979 survey for Forest Oil Corporation, which documented a side-scan sonar-target and a magnetic anomaly of 500+ gammas over a distance of 1,000 ft (305 m) (Hole 1979). John E. Chance & Associates, Inc. later recorded Site 328 in a pipeline right-of-way remote-sensing survey performed for Shell Pipe Line Corporation (DuVal et al. 1996). Both Hole and DuVal et al. tentatively identified Site 328 as *Sheherazade*.

In 2005, PBS&J conducted a remote-sensing and diver investigation of Site 328 as part of its NRHP evaluation of selected Gulf of Mexico shipwrecks (Enright et al. 2006). That investigation recorded a capsized, steel-hulled vessel, with a visible length of approximately 545 ft (166 m) on the sonar image (Figure A-3), and a magnetic anomaly with a relative amplitude of –5,625 to +30,425 gammas. Also recorded were two 30-ft-wide (9.1-m) torpedo holes on the wreck's starboard side. The archaeological data combined with subsequent historical research confirmed the identity of Site 328 as *Sheherazade*, and PBS&J recommended that the wreck be considered eligible for the NRHP (nomination status is pending).

The hindcast study for Hurricane Rita (Oceanweather, Inc. 2006) estimated a peak sustained wind speed over *Sheherazade* of 76 mph (34.0 m/s) and a maximum significant wave height of 29.9 ft (9.1 m). PBS&J again surveyed *Sheherazade* for the present study on May 9, 2007. Water depth on-site was approximately 50 ft (15.2 m) to the top of the wreck and 77 ft (23.5 m) to the seafloor. Based on initial analysis of the raw sonar data, there were no noticeable hurricane-related impacts to the site relative to the 2005 sonar imagery (see Figure A-3). Bow orientation remained identical to its 2005 position (approximately 78 degrees), and there was no apparent change to the few recognizable features of the upside-down hull; namely, the torpedo impact holes and the extant starboard propeller. Both torpedo impact holes measure approximately 30 ft (9.1 m) on the sonar image and show no evidence of increased size since 2005. Based on this in-field analysis, the decision was made, with the concurrence of the Contracting Officer's Technical Representative (COTR), to remove *Sheherazade* from further survey or diving consideration (Gearhart 2007). Further analysis of the mosaiced sonar data during the report-writing phase of this study, however, revealed subtle evidence of hull degradation since 2005. Adjacent to the northernmost torpedo hole (at the bow end) is an area where the linear pattern of the bilge keels has been distorted, and there appear to be several small hull fissures (Figure A-4). The imagery is evocative of the area of weakened hull structure present in the

2004 sonar data from Site 323 (see Section 4.3.3). *Sheherazade*'s area of hull degradation extends in a triangular pattern approximately 24 ft (7.3 m) to the wreck's port side, beginning at the visible edge of the torpedo hole. This degradation can be partially attributed to a weakening of structural elements at the time of the initial torpedo explosion. Whether the increased degradation since 2005 is attributable to normal erosion of metals in salt water, or has been accelerated by hurricane forces, cannot be determined with the available data.

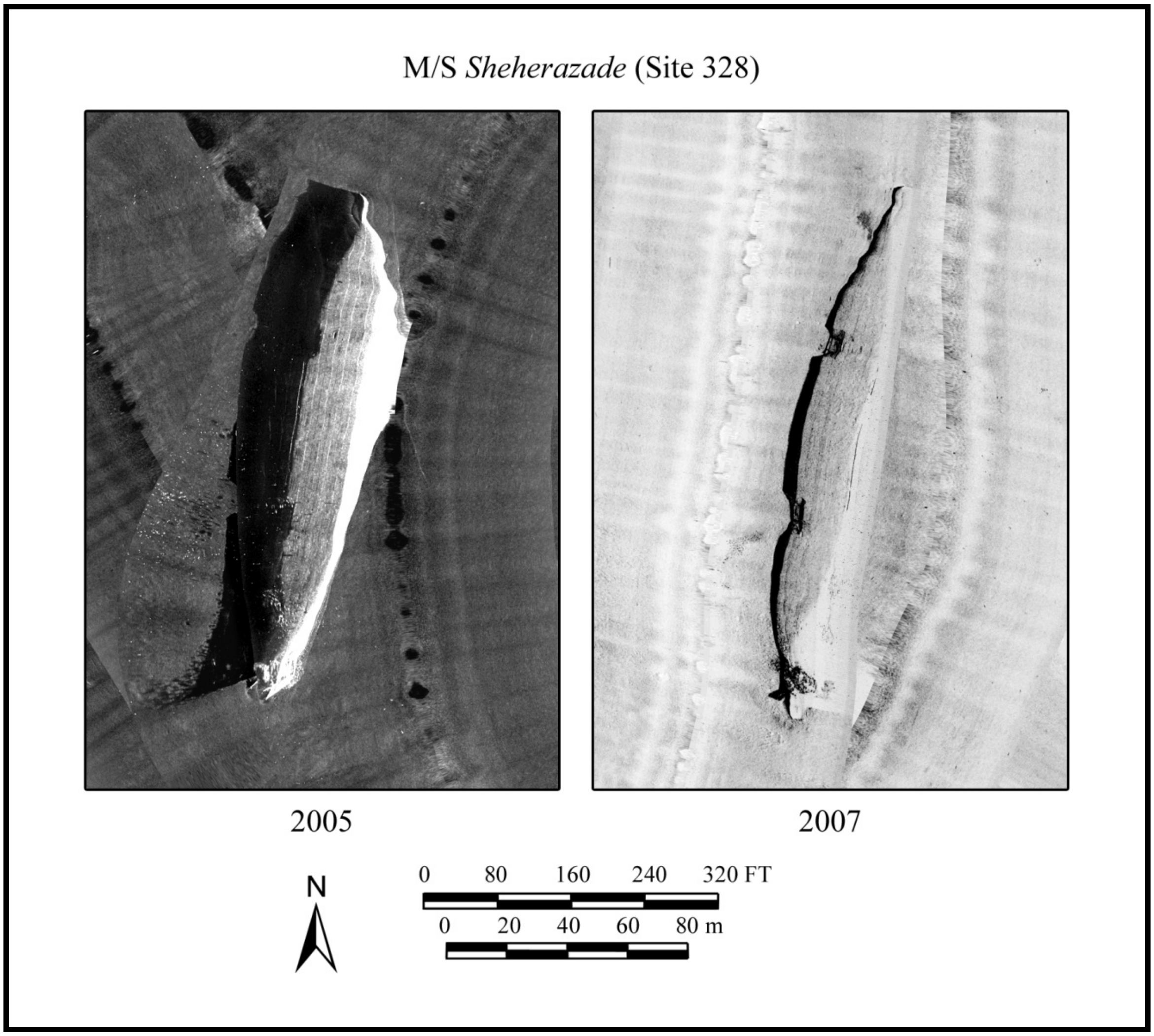


Figure A-3 Pre- and posthurricane sonar imagery of *Sheherazade*.

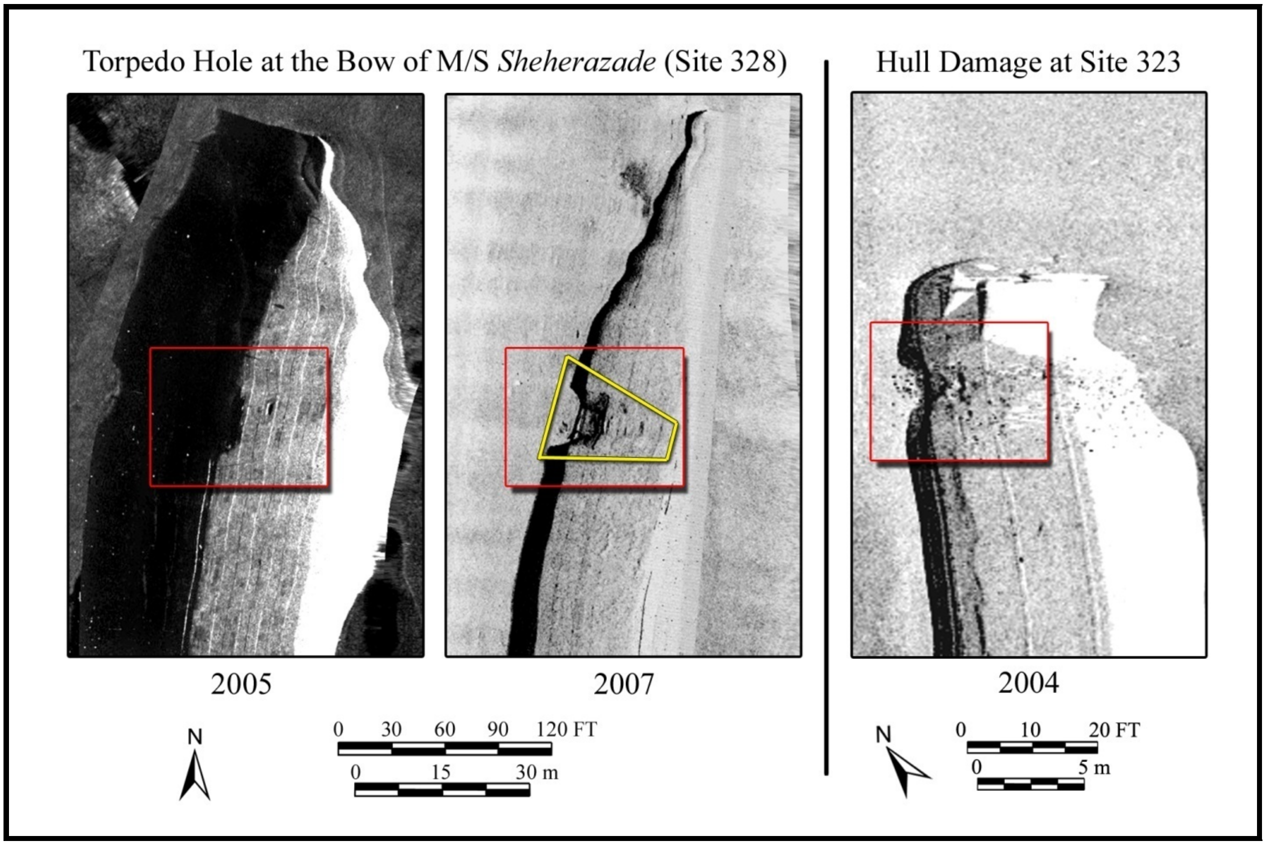


Figure A-4 Comparison of hull damage at *Sheherazade* and Site 323.

Two pipelines are located approximately 2,000 ft (610 m) east and west of the site, with a well 1,250 ft (381 m) to the southwest. No hurricane damage was reported at these structures. The closest reported petroleum industry damage near *Sheherazade* was an Apache Corporation pipeline pulled up 3 mi (4.8 km) northeast of the site.

R.M. Parker, Jr.

R.M. Parker, Jr. (BOEMRE vessel ID 432) is located in the South Timbalier lease block area, 69.6 mi (112.0 km) west of Hurricane Katrina's path. *R.M. Parker, Jr.* was a 425-x-57-x-33-ft (129.5-x-17.4-x-10.1-m), 7,000-gross-ton tanker built in 1919 for the United States Shipping Board (USSB) by the Moore Shipbuilding Company, of Oakland, California (Figure A-5). Initially named *Imlay,* it was intended for the U.S. maritime fleet during World War I, but was not completed in time to see wartime service (Enright et al. 2006). After the war, the USSB chartered *Imlay* for petroleum transport before eventually selling the tanker to private interests. From 1923 to 1942, *Imlay* was employed as a coastal oil tanker, operating mostly out of Texas, and its name was changed to *R.M. Parker, Jr.* in 1941. After U.S. entry into World War II, *R.M. Parker, Jr*. was requisitioned by the WSA to continue service as a coastal oil tanker for the U.S. Merchant Marine. In the early morning of August 13, 1942, *R.M. Parker, Jr.* was traveling alone in ballast, westbound along the northern Gulf of Mexico coastline, when it was struck on its port side by two torpedoes launched from U-*171*. All 44 crew and marine guards escaped in the lifeboats, and *R.M. Parker, Jr.* finally sank 8½ hours after being hit (Wiggins 1995:111–112).

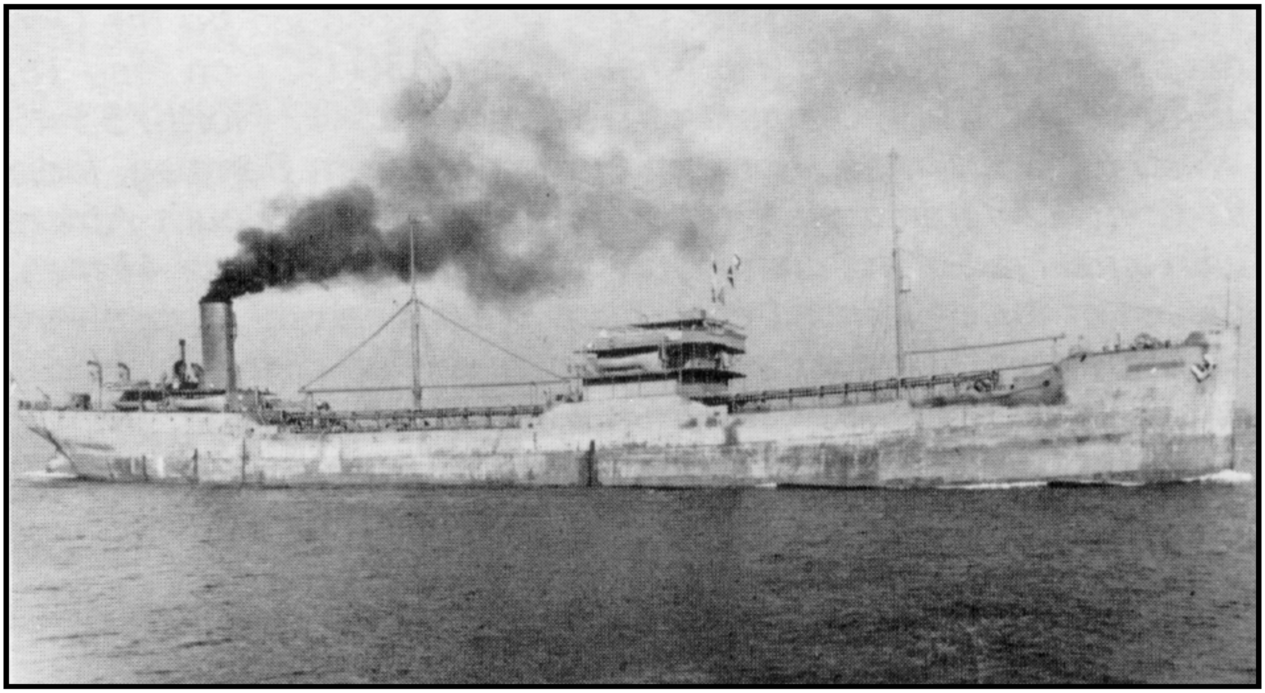


Figure A-5 SS *R.M. Parker, Jr.*

Site 432 was first recorded in 2003 during a Cochrane Technologies, Inc. lease block survey for Spinnaker Exploration Company, LLC (el Darragi et al. 2003). That survey recorded a shipwreck rising 24 ft (7.3 m) above the seafloor, along with a possible debris field several hundred feet away. PBS&J conducted a remote-sensing survey and diver investigation of the wreck for a 2005 NRHP site evaluation (Enright et al. 2006). The sonar survey showed the wreck broken into two pieces: a 175-ft-long (53.3-m) section from the bridge deck to the transom, and a partially buried section measuring approximately 234–275 ft (71.3–83.8 m) and comprising the forward section of the bridge deck to the bow (Figure A-6). The aft section was sitting keel-down, while the forward piece was lying on its starboard side. Segments of the topgallant forecastle, main, bridge, and poop decks were clearly visible in the sonar record. Total vessel dimensions, based on the sonar data, measured between 409 and 450 ft long (124.7–137.2 m) (factoring in the partially buried bow), 55 ft (16.8 m) wide, and with a 30-ft (9.1-m) depth of hold at the main deck level (and 48–50 ft [14.6–15.2 m] at the forecastle deck). Wreck height off the seafloor was approximately 23 ft (7.0 m). Based on the archaeological diving, remote-sensing data, and archival research, PBS&J confirmed the identity of Site 432 as *R.M. Parker, Jr.* and recommended the site be determined eligible for the NRHP (nomination status is pending).

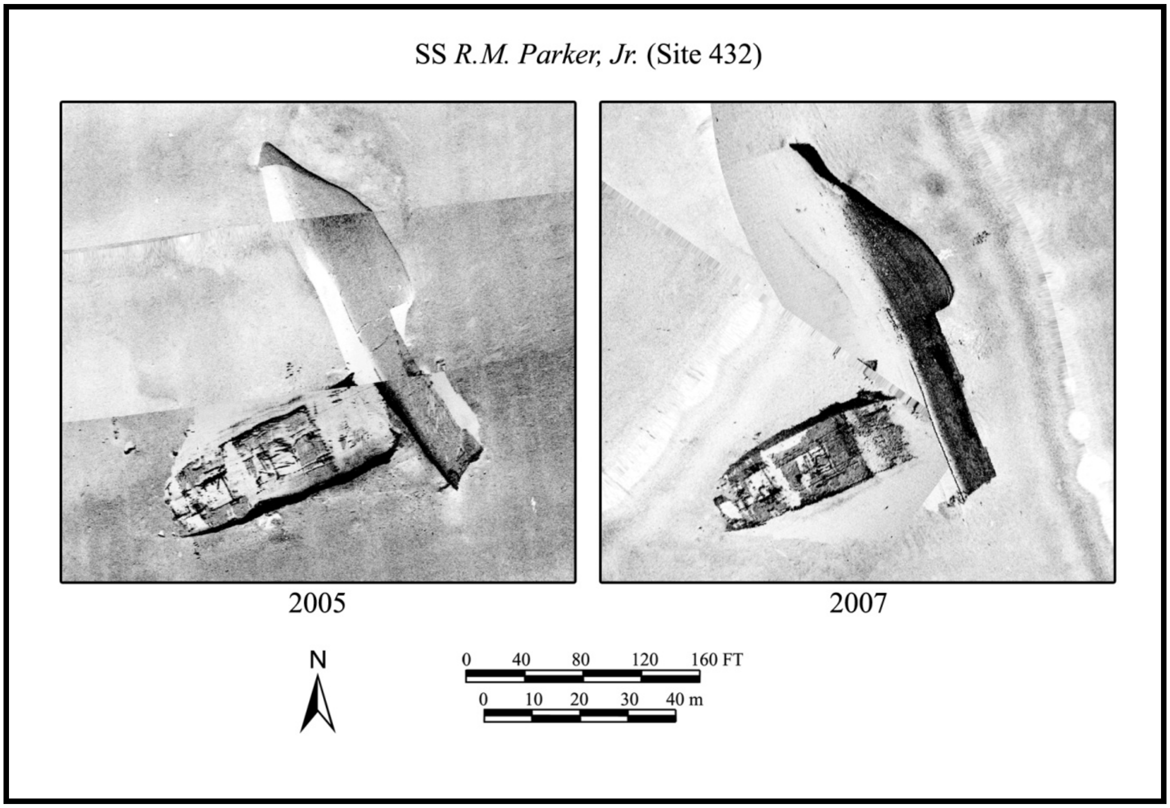


Figure A-6 Pre- and posthurricane sonar imagery of *R.M. Parker, Jr.*

The hindcast study for Hurricane Katrina (Oceanweather, Inc. 2006) estimated a peak sustained wind speed over *R.M. Parker Jr.* of 51 mph (22.8 m/s) and a maximum significant wave height of 22.0 ft (6.7 m). PBS&J resurveyed the site for the present study on May 9, 2007. Water depth was approximately 56 ft (17.1 m), and maximum wreck elevation off the seabed was 23 ft (7.0 m). Ten transects were surveyed over the site, and the resulting sonar data showed no noticeable alterations to *R.M. Parker, Jr.* relative to its 2005 condition (see Figure A-6). There is no apparent vertical or lateral displacement of the two hull sections, nor evidence of any structural collapse. Poop and main deck features identifiable in the 2005 sonar imagery (i.e., linear features indicating catwalks and hatchways) can also be clearly seen in the posthurricane data. However, an unidentified 13-x-10-ft (4.0-x-3.0-m) object that was recorded approximately 435 ft (133 m) southwest of the wreck's stern in 2005 (Enright et al. 2006) was no longer visible in 2007. The closest pipeline to *R.M. Parker, Jr.*, ¾ mi (1.2 km) northeast, received no reported damage. The closest reported damage was to a Forest Oil Corporation pipeline 7.5 mi (12.1 km) to the northeast. Based on these factors and the analysis of the sonar data, no further dive investigation of *R.M. Parker, Jr.* was recommended (Gearhart 2007).

SITE 389

Site 389 is located in the South Timbalier lease block area, 63.3 mi (101.9 km) west of Hurricane Katrina's path. Based on its proximity to several of the primary and secondary selected study sites, Site 389 was one of three sites added to the survey plan while fieldwork was in progress, with the concurrence of the COTR. The site is suspected to be the wreck of *J.A. Bisso*, a 224-ton towboat that was built in 1906 and foundered in 1957 (BOEMRE wreck database). Site 389 was located and tentatively identified as *J.A. Bisso* by a Northland Research, Inc. lease block survey in 2000, and was surveyed again in March 2005.

The hindcast study for Hurricane Katrina (Oceanweather, Inc. 2006) estimated a peak sustained wind speed over Site 389 of 61 mph (27.3 m/s) and a maximum significant wave height of 23.3 ft (7.1 m). PBS&J conducted a sonar-only survey of *J.A. Bisso* on May 9, 2007. Based on the 2007 sonar data, the wreck appears to be listing to its port side, as a vertical portion of the starboard bow hull is visible (Figure A-7). More significantly, a large unidentified object, visible in the 2005 sonar on the port side, just forward of amidships, is no longer present. There is also evidence that an approximately 35-ft-long (10.7-m) section of the aft port gunwale and deck have been buried. The burial process seems to have begun prior to 2005, as the sonar imagery from that year also shows evidence of partial burial in the same area, though to a lesser extent. A large scour depression also appears to have formed around Site 389. The scour extends northwest, perpendicular to the wreck hull for approximately 330 ft (101 m), and is approximately 160 ft (49 m) wide at its widest point adjacent to the bow and stern of the vessel. The size of the prehurricane scour pattern was indeterminate from the available sonar data. The prehurricane sonar data for Site 389 is low resolution, so direct comparison with the poststorm data is largely inconclusive, and there has been no known prehurricane diver recording of the site. However, based on the available imagery, there did not appear to be any significant structural or positional changes to the site since the 2005 survey. Accordingly, no further dive investigation was recommended (Gearhart 2007). The closest reported petroleum industry damage to Site 389 was to a Forest Oil Corporation pipeline 3 mi (4.8 km) to the northeast, while the closest undamaged pipeline was ½ mi (0.8 km) to the north.

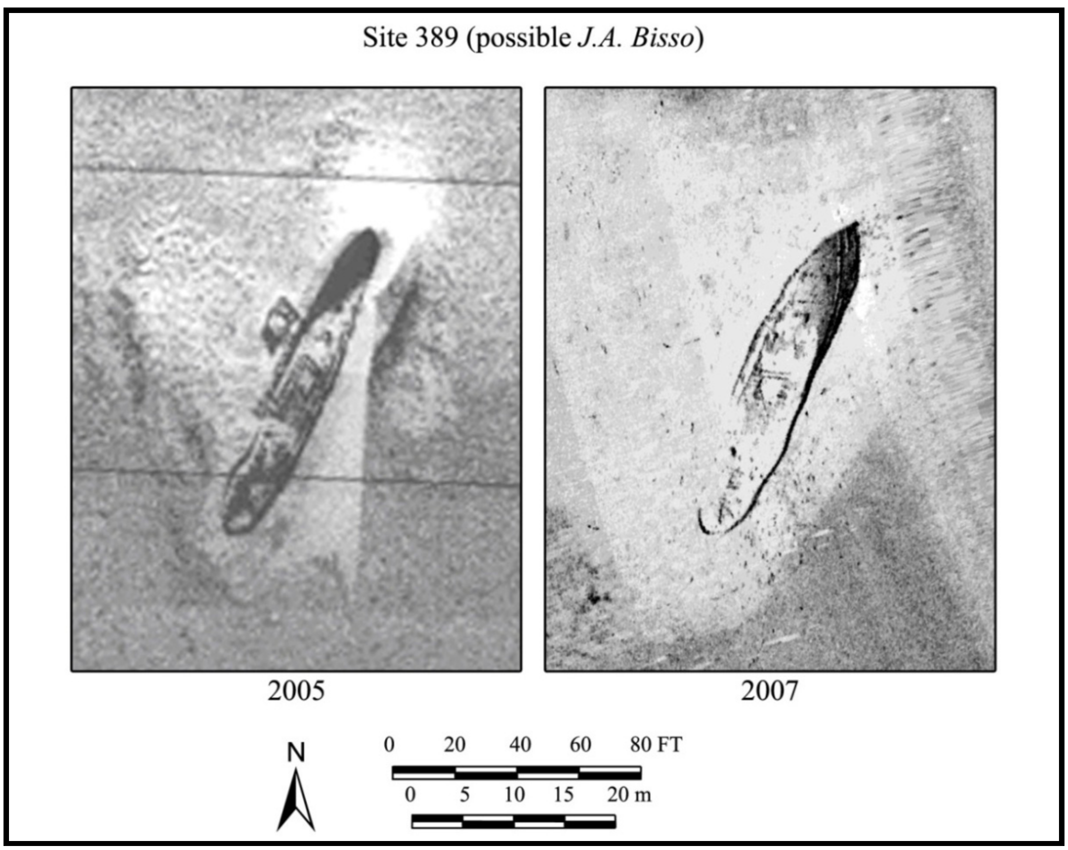


Figure A-7 Pre- and posthurricane sonar imagery of Site 389.

SITE 343

Site 343 is located in the High Island lease block area, 23.4 mi (37.6 km) west of Hurricane Rita's path. Based on its proximity to several of the primary and secondary selected study sites, Site 343 was the second of three sites added to the survey plan while fieldwork was in progress. According to the BOEMRE shipwreck database, Site 343 is an unknown wreck that was first recorded in a 1997 lease block survey (K-C Offshore, LLC 1997). That survey recorded a low-resolution sonar target, tentatively identified as a shipwreck, between 50 and 140 ft (15.2–42.7 m) long and 20 and 35 ft (6.1–10.7 m) wide (Figure A-8). A subsequent survey in 1998 confirmed that it was a modern wreck.

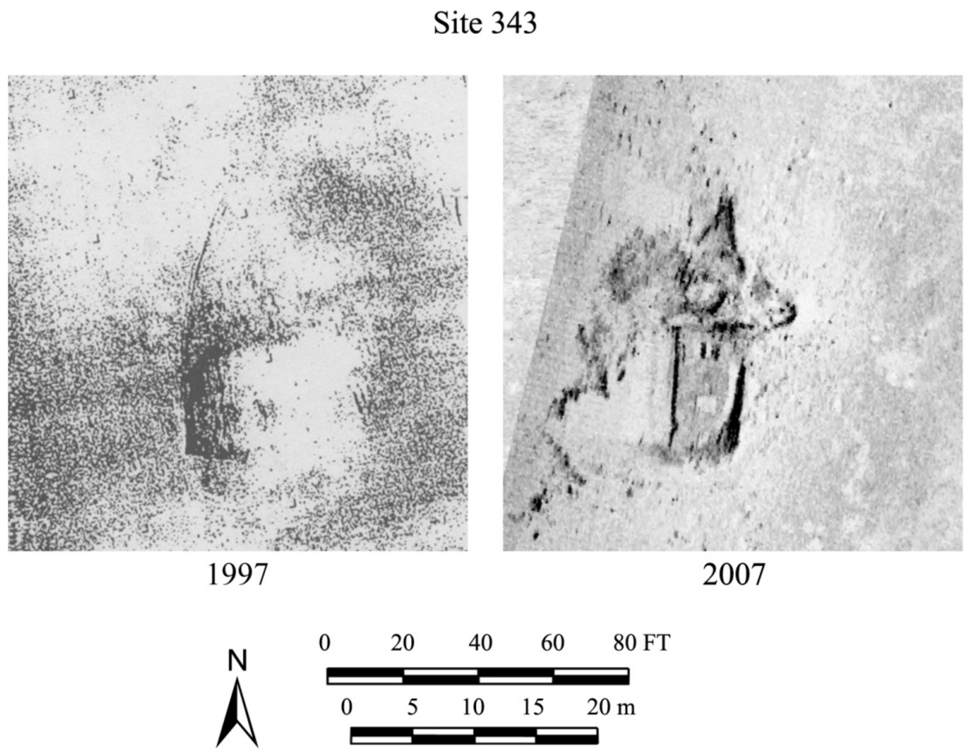


Figure A-8: Pre- and posthurricane sonar imagery of Site 343.

The hindcast study for Hurricane Rita (Oceanweather, Inc. 2006) estimated a peak sustained wind speed over Site 343 of 70 mph (31.3 m/s) and a maximum significant wave height of 18.7 ft (5.7 m). PBS&J conducted a sonar-only survey of the site on May 11, 2007. The sonar imagery confirmed a shipwreck in approximately 45 ft (13.7 m) of water (37 ft [11.3 m] over top of the wreck), measuring approximately 62 x 20 ft (19.8 x 6.1 m). The vessel has a square stern and sharp bow. Two square hatchways are visible along the centerline, aft of amidships, and there is a significant amount of amorphous material covering the forward pilothouse area and extending out approximately 13 ft (4.0 m) to the starboard (east) side of the wreck. This material may be indicative of the superstructure, outriggers, and netting of a trawler. Alternately, it may be collapsed superstructure and/or intrusive snagged nets. The prehurricane sonar data for Site 343 is low resolution, so direct comparison with the poststorm data is largely inconclusive, and there has been no known prehurricane diver recording of the site. However, based on the available imagery, there did not appear to be any significant structural or positional changes to the site since the 1997 survey. Accordingly, no further dive investigation was recommended (Gearhart 2007). No damage was reported to the closest pipeline, a little over ½ mi (0.8 km) west of the site, while the closest reported damage was to a Manta Ray Gathering Company, LLC pipeline 6.6 mi (10.6 km) southwest and farther from the storm's path.

USS *HATTERAS*

USS *Hatteras* (BOEMRE vessel ID 236) is a Union gunboat that was captured and sunk 14 mi (22.5 km) off the Texas coast in January 1863. It is located in the Galveston lease block area, 77.7 mi (125.0 km) west of Hurricane Rita's path. *Hatteras* was built in 1861 as the merchant ship *St. Mary*, at Harlan and Hollingsworth of Wilmington, Delaware. It was an iron-hulled side-wheel steamer intended for use in the Charles Morgan Line of Gulf of Mexico packet ships. The vessel measured 210 x 34 x 18 ft (64.0 x 10.4 x 5.5 m), with a three-masted schooner rig (Figure A-9), and was powered by a 500-horsepower walking beam engine (Arnold and Anuskiewicz 1995). The U.S. Navy acquired the *St. Mary* in September 1861, renaming the ship *Hatteras,* and arming it with four 32-pounders, two 30-pounders, one 20-pounder, and one 8-pounder. After a brief tour in the South Atlantic Blockading Squadron, *Hatteras* was transferred to the Western Gulf Blockading Squadron where it captured seven Confederate blockade-runners.

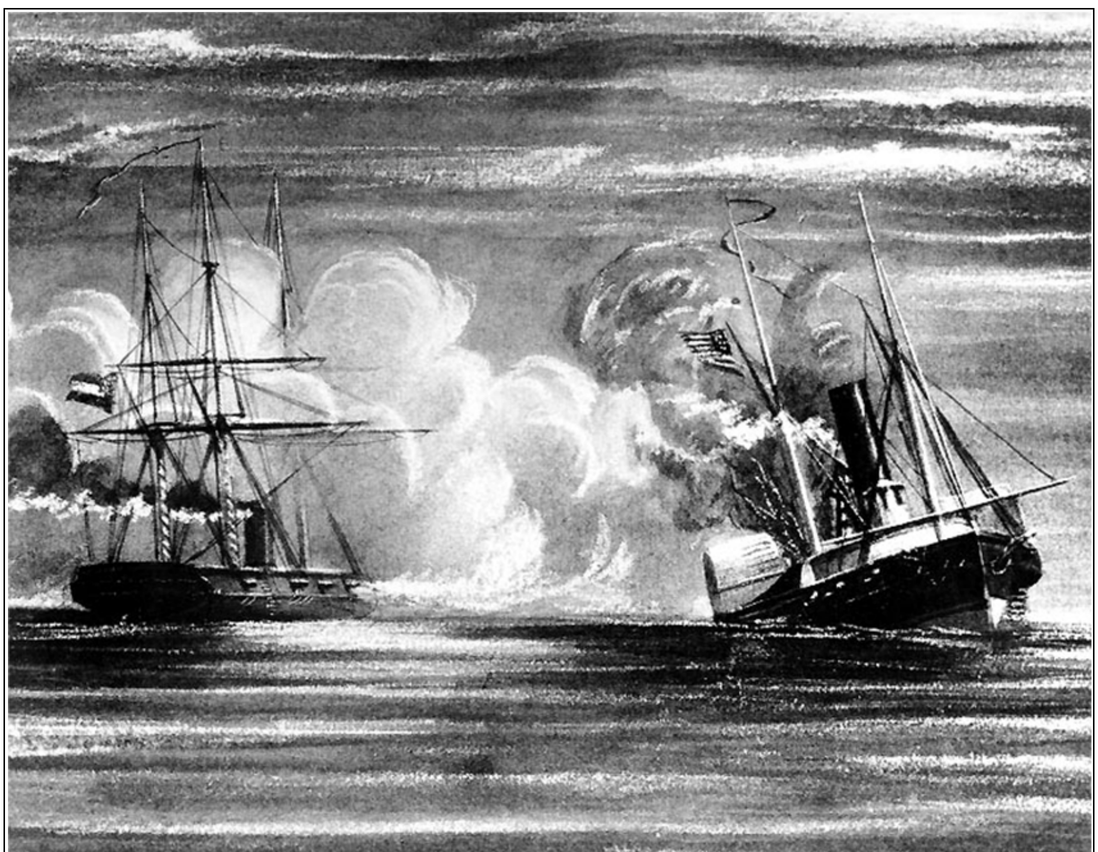


Figure A-9 CSS *Alabama* sinks USS *Hatteras*, January 1863 (Naval History and Heritage Command 2010).

In January 1863, *Hatteras* was off Galveston, joining Rear Admiral David Farragut's blockade of the Texas coast. On the morning of January 11, *Hatteras*, under the command of Captain Homer C. Blake, was ordered to pursue a ship approaching Galveston and flying a British flag. Just after sunset, and several miles away from the rest of the Union fleet, *Hatteras* caught up to the unknown vessel, which then raised a Confederate flag, identified itself as the famed raider CSS *Alabama* (under command of Raphael Semmes), and began firing. The ensuing battle lasted only 13 minutes, ending after a shell exploded in the overmatched *Hatteras*'*s* engine cylinder, disabling the walking beam (Arnold and Anuskiewicz 1995). Captain Blake surrendered the burning and sinking *Hatteras* to Semmes, who then sent his own boats to rescue the survivors (*Hatteras* suffered two dead and five wounded, while *Alabama* had only two injured). *Hatteras* sank in 60 ft (18.3 m) of water, 45 minutes after the engagement had begun.

The site was discovered in the mid-1970s by treasure hunters who then attempted to arrest the wreck in Admiralty court after salvaging several artifacts. The Navy ultimately won the court judgment and retained ownership of the wreck (U.S. District Court for the Southern District of Texas, Galveston Division n.d.). While litigation was ongoing, the Bureau of Land Management (a precursor to the BOEMRE), along with the Texas Historical Commission (THC) and the Institute of Nautical Archaeology at Texas A&M University, conducted a series of remote-sensing surveys over the site (Arnold and Hudson 1981). In 1992, a 3-year program of site monitoring and mapping was initiated (Arnold and Anuskiewicz 1995). Those investigations revealed that very little of the wreck remained exposed above the sand; both paddlewheel hubs and parts of the steam engine extended a maximum of 4 ft (1.2 m) above the seafloor, and there was a small section of encrusted iron towards the bow (Figure A-10). By 1994, the bow remains had been buried (Arnold and Anuskiewicz 1995). The site was subsequently designated a State Archeological Landmark and listed in the NRHP.

PBS&J resurveyed the site in 2005 as part of the ongoing periodic site monitoring (Enright et al. 2006). The resulting sonar and dive data showed that the site remained essentially unchanged since 1994. Exposed wreckage was limited to the upper portions of both paddlewheel hubs, a knuckle connecting two iron rods (located between the hubs) and three cylinders associated with the steam chest (Figure A-11).

The hindcast study for Hurricane Rita (Oceanweather, Inc. 2006) estimated a peak sustained wind speed (5.4 mi [8.7 km] east of the site) of 52 mph (23.2 m/s) and a maximum significant wave height of 12.5 ft (3.8 m). In 2007 PBS&J conducted a sonar-only survey of *Hatteras*, which revealed virtually no change to the site since 2004. Once again both paddlewheel hubs, the iron knuckle, and the steam chest cylinders were the only wreck features that remained exposed. Based on this evidence, PBS&J recommended no further dive investigations to determine posthurricane impacts (Gearhart 2007). There was also no petroleum industry damage reported in the vicinity of *Hatteras*. The closest impacted structure was a Manta Ray Gathering Company, LLC pipeline, 28 mi (45.1 km) northeast.

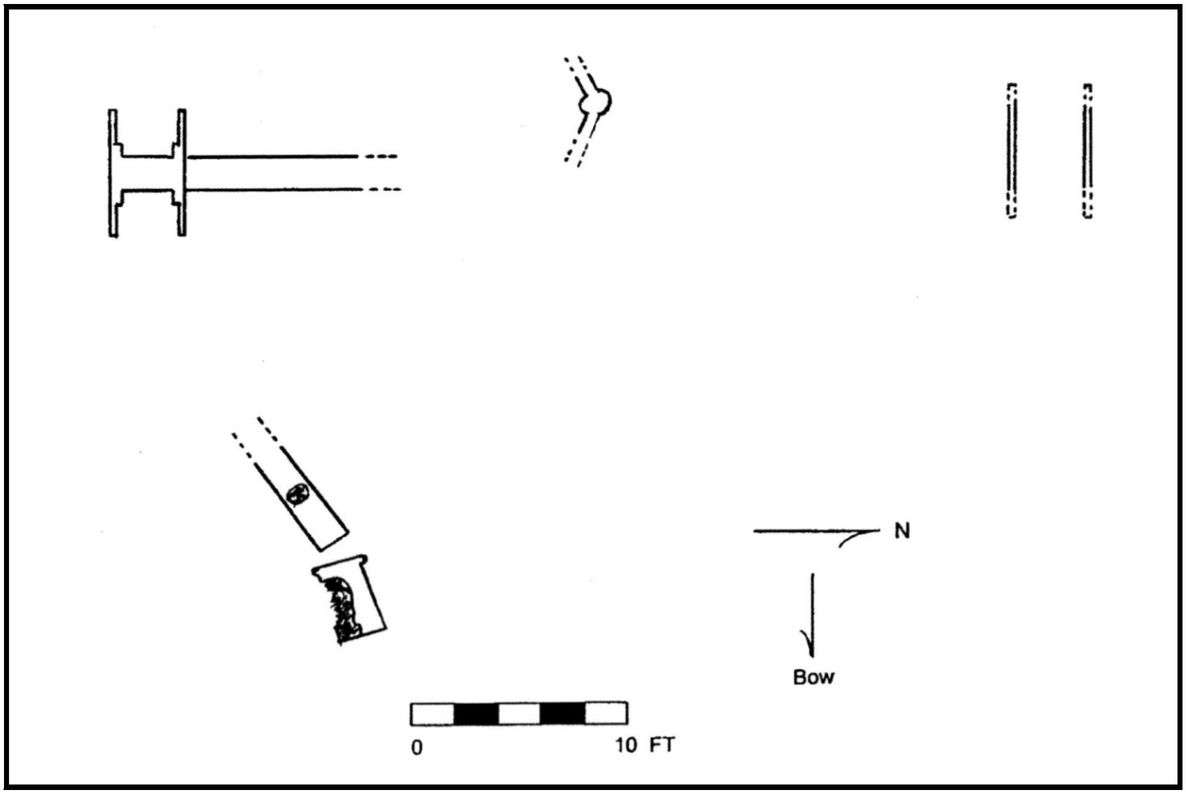


Figure A-10 1994 site plan of USS *Hatteras* (Arnold and Anuskiewicz 1995).

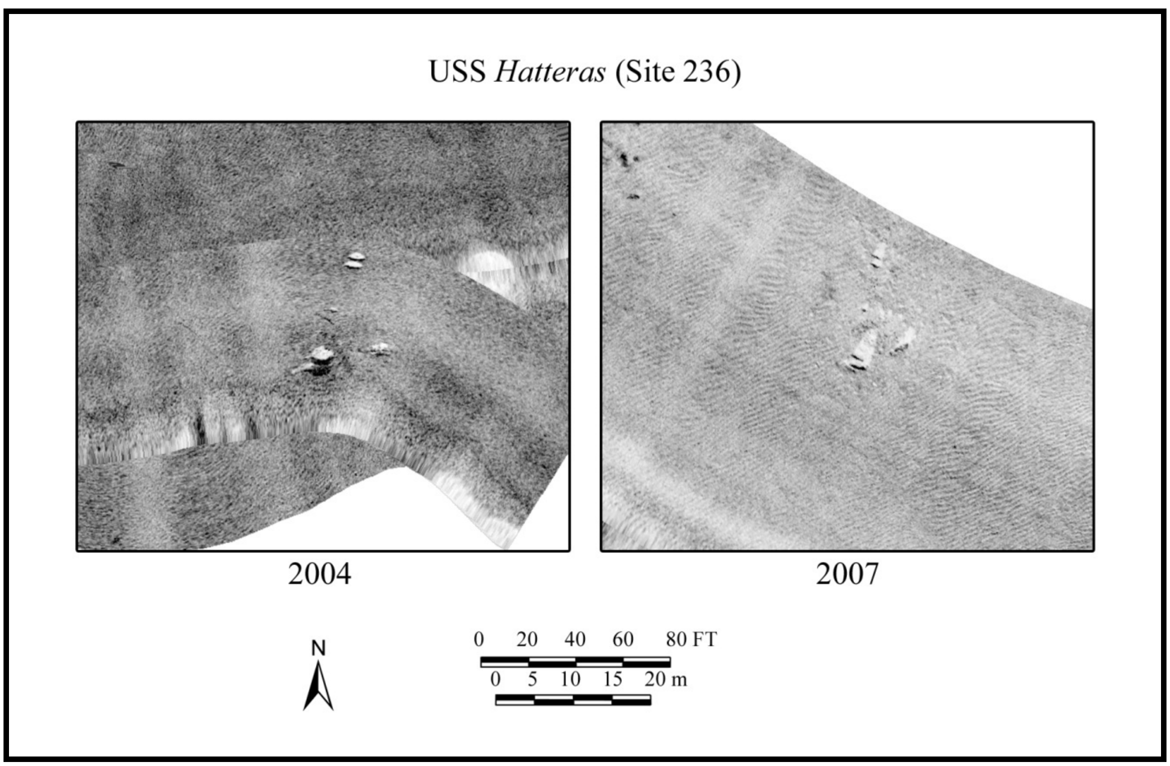


Figure A-11: Pre- and posthurricane sonar imagery of USS *Hatteras*.

JOSEPHINE

In addition to the 10 wrecks initially selected for this study, PBS&J evaluated sector-scan sonar imagery of the steamship *Josephine* that had been collected in August 2007. *Josephine* (BOEMRE vessel ID 365) was an iron-hulled side-wheel steamer built by Harlan and Hollingsworth in 1867 for Charles Morgan's Louisiana and Texas Railroad and Steamship Company. The steamer was 235 ft (71.6 m) long, 34 ft (10.4 m) abeam, with an 18.5-ft (5.6-m) depth of hold, and was powered by a low-pressure, 50-inch-diameter (127-centimeter [cm]), 800-horsepower engine with 11-ft (3.4-m) stroke, provided by Morgan Iron Works Company. *Josephine* had a round stern, two decks, two masts, two cabins, and a 250-passenger capacity. Charles Morgan was among the passengers on the packet steamer's maiden voyage that carried cargo and passengers from Wilmington, Delaware, to New Orleans (via Havana and Key West) in February 1868. Upon arrival in New Orleans, *Josephine* was assigned to run freight, passengers, and mail biweekly between Brashear City (later renamed Morgan City), Louisiana, and Galveston, Texas. The steamer ran aground on the Brazos Bar in 1868, but was removed, seemingly unscathed, a testament to the ship's durability. On January 15, 1881, *Josephine* was reassigned to carry cargo and passengers between New Orleans and Havana. After arriving safely in Havana, *Josephine* disembarked for New Orleans with a cargo of tobacco, cigars, and passengers, making stops at Key West and Cedar Key, Florida, on the way. On the last leg of the trip the steamer began taking on water, likely as a result of damage from a severe winter storm. All of the passengers and crew were able to safely abandon ship, but the vessel was lost (at a value of $75,000) in approximately 38 ft (11.6 m) of water off the coast of Biloxi, Mississippi (Irion and Ball 2001:53–55; BOEMRE database).

A 1997 side-scan sonar image of the wreck revealed it sitting upright with approximately 20 ft (6.1 m) of relief off the bottom, and the interior filled with sediment (Figure A-12). The walking beam engine, boilers, and paddlewheels were all in situ. The wreck was investigated by archaeologists in 2000, who discovered most of the hull was buried and the upper hull (above the waterline) was missing, and who speculated that the hull remains intact below the waterline. The attachment points for the paddlewheels remained intact as did some of the paddlewheels' iron spokes. The outline of the hull was visible except for the bow, which was completely buried. The walking beam was found toppled on the starboard side, but the paddlewheel shafts were still in their pillow block bearings. The top of the two boilers (observed in the 1997 side-scan sonar, but mostly buried at the time of the 2000 dive investigations) were observed, surrounding the base of the smokestack (Irion and Ball 2001:55–56; BOEMRE database).

The hindcast study for Hurricane Rita (Oceanweather, Inc. 2006) estimated a peak sustained wind speed over *Josephine* of 86 mph (38.4 m/s) and a maximum significant wave height of 27.6 ft (8.4 m). In 2007 a sector-scan sonar survey of *Josephine* was conducted. The resulting images indicate that the wreck received no obvious damage from Hurricanes Katrina (which passed 46 mi [74 km] to the west) or Ivan (which passed 58 mi [93 km] to the east in 2004). All features of the hull and steam machinery described by Irion and Ball (2001) remain visible and apparently undamaged. There is marginally less hull outline visible towards the stern, which may be the result of increased burial or erosion of the exposed iron. Conversely, the area surrounding the boilers appears marginally more exposed. According to Irion and Ball (2001), only the tops of the boilers were exposed during the 2000 diving investigation. The 2007 data show evidence of slight scouring port, starboard, aft, and in-between the boilers. A review of previous side-scan sonar images and diver accounts indicate that the wreck has existed in various states of burial since its discovery. Whether the change in level of burial is due to effects of passing storms is indeterminable at this time.

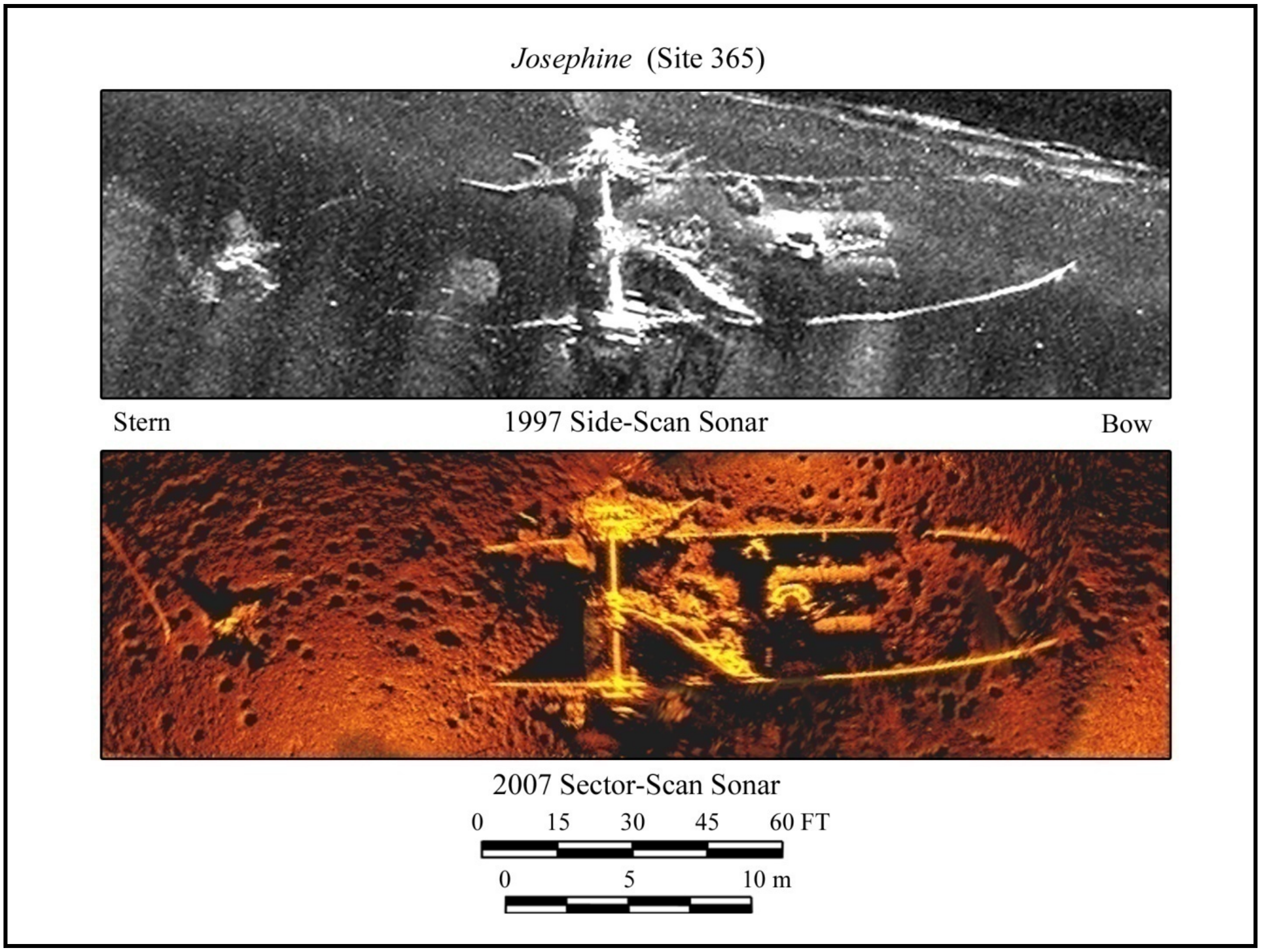


Figure A-12   Pre- and posthurricane sonar imagery of *Josephine*.

Finally, both within and outside the wreck is a pattern of craters in the sediment, similar to that observed at the site of *Gulf Tide*. This phenomenon is believed to be caused by the evacuation of gas pockets, presumably air, trapped in the sediment and under parts of the wreck. It seems likely that these pockets of air accumulated beneath the wreckage during the recent hurricanes, then continued releasing to the surface following passage of the storms, thus preserving the small craters over the site.

Literature Cited

American Merchant Marine at War. 1998. U.S. Naval Armed Guard casualties during World War II. Internet website: http://www.usmm.org/armedguard.html. June.

Arnold, J.B. III and R.J. Anuskiewicz. 1995. USS *Hatteras*: site monitoring and mapping. In: Underwater Archaeology Proceedings from the Society for Historical Archaeology Conference. Washington, DC. January 1995.

Arnold, JB. III and J. Hudson. 1981. The USS *Hatteras*: a preliminary report on remote sensing data and litigation. In: Cockrell, W.A., ed. The Realms of Gold: The Proceedings of the Tenth Conference on Underwater Archaeology. San Marino, CA: Fathom Eight.

Dothan Eagle [AL]. 1950. "Tanker race started by maritime nations." 10 January, p. 1 Sports.

DuVal, B.J., M.A. Savarino, and L. Landry. 1996. Archeological engineering, and hazard study of proposed auger expansion Phase 3 pipeline route from Block 331 to Block 28, ship shoal area. John E. Chance & Associates, Inc. Submitted to Shell Pipe Line Corporation.

el Darragi, S.D. and A.R. Saltus, Jr. 2001. Archaeological, engineering, and hazard study: proposed 8-inch gas pipeline route from well #2 Vermillion Area Block 196 to Sub-Sea Tie-In Vermillion Area Block 206. Prepared for McMoRan Oil & Gas, LLC by Cochrane Technologies, Inc.

———. 2003. Archaeological and hazard study of Block 98 South Timbalier Area (OCS-G-24962). Cochrane Technologies, Inc. Submitted to Spinnaker Exploration Company, LLC.

Enright, J.M., R. Gearhart II, D. Jones, and J. Enright. 2006. Study to conduct National Register of Historic Places evaluations of submerged sites on the Gulf of Mexico Outer Continental Shelf. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2006-036.

Gearhart, R. 2007. May 2007 geophysical survey trip report: impacts of recent hurricane activity on historic shipwrecks in the Gulf of Mexico. Submitted on July 9 to U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA.

Hole, F. 1979. Archaeological report analysis: Eugene Island Blocks 190 and 191 (OCS-G-3995 and -8434). Submitted to Forest Oil Corporation.

Irion, J.B. and D.A. Ball. 2001. "The *New York* and the *Josephine*: two steamships of the Charles Morgan Line." The International Journal of Nautical Archaeology 30.1:48–56

K-C Offshore, LLC. 1997. Geophysical survey report, Block 164, High Island Area. Minerals Management Service Archeological Resource Information database, Vessel ID 343.

Monier, P.K., S. Dean el Darragi, and A.R. Saltus, Jr. 1998. Archaeological and hazard report of Blocks 195, 196, 207, and 208 OCS-G-19759, -19760, -19761, and -11876 Vermillion Area. C&C Technologies, Inc. Submitted to Shell Deepwater Development Systems, Inc.

Naval History and Heritage Command. 2010. Online library of selected images. USS *Hatteras* (1861-1869). Photo #NH53690. Internet website: http://www.history.navy.mil/photos/images/h53000/ h53690.jpg. March 16.

Oceanweather, Inc. 2006. Hindcast data on winds, waves, and currents in northern Gulf of Mexico in Hurricanes Katrina and Rita.

U.S. Coast Guard (USCG). 1942. Ship movement cards. Record Group 38, National Archives, Washington, DC.

U.S. District Court for the Southern District of Texas, Galveston Division. n.d. Hatteras, Inc. Plaintiff v. The USS Hatteras, her engines, armament, apparel, cargo, appurtenances, etc., *in rem*, and United States of America, *in personam* Defendants. Civil Action No. G-78-77.

Wiggins, M. 1995. Torpedoes in the Gulf: Galveston and the U-boats, 1942–1943. College Station, TX: Texas A&M University Press.

Appendix B

Additional Archival Research

APPENDIX B: ADDITIONAL ARCHIVAL RESEARCH

In July 2007, the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) issued Modification 0001 to Contract M07PC13010, which funded an archival research trip to The Mariners' Museum, in Newport News, Virginia, the Library of Congress, and the National Archives branches in Washington, D.C., and College Park, Maryland. This trip was designed to identify materials at each repository that may improve knowledge of the history, construction characteristics, and wrecking event of the selected study wrecks, or, in the case of Site 323, provide information to aid in vessel identification. In addition to the sites selected for diver investigation, BOEMRE provided PBS&J with a list of other historic shipwrecks in their database that were considered high priority sites. If possible, the archival records were to be inspected for information on these vessels as well. Due to time constraints, only the two highest priority vessels, *Bradford C. French* and *Sarah Barnes*, were able to be researched directly. Some information on *Hamlet* and *Orient* was obtained later through correspondence with the Smithsonian National Museum of American History. A vessel-specific summary of the record collections inspected at each repository, and the results of that research are presented here.

BRADFORD C. FRENCH

Bradford C. French was a three-masted schooner, carrying $50,000 of molasses from San Juan, Puerto Rico, to New Orleans when it was struck by a hurricane on June 5, 1916. The vessel wrecked approximately 60 mi (97 kilometers [km]) east of South Pass, Mississippi, its hull and cargo a total loss, though the captain and eight crew were rescued. According to the BOEMRE database (Vessel ID 15303), the wreck may have been discovered in the Viosca Knoll lease block area by a 2003 C&C Technologies pipeline survey; however, a subsequent remotely operated vehicle (ROV) inspection of the wreck by C&C refuted this identification (Church and Warren 2008)

Mariners' Museum

Bradford C. French's entry in the *Record of American and Foreign Shipping* was checked for every year of its service (American Bureau of Shipping [ABS] 1884–1916). This source describes the vessel as a Tern (or three-masted) schooner, built by D. Clark of Kennebunkport, Maine, in 1884 (Official No. 3282). It was 184.5 feet (ft) (56.2 meters [m]) long and 37.5 ft (11.4 m) abeam, with a 19.2-ft (5.9-m) depth of hold. The hull was constructed of oak, hackmatack, yellow pine, and iron and copper fastenings, and it was further equipped with an oscillating engine. *Bradford C. French* was originally owned by J.B. Phillips, and sailed out of Taunton, Massachusetts. In 1903 Phillips sold the vessel to Crowell & Thurlow, who changed its home port to Boston.

There is some documentary confusion about the number of decks contained on *Bradford C. French*. The ABS records from 1884–1888 document it having two decks, while from 1889–1903 it is listed with one deck, and from 1904–1916 it is once again listed with two decks. Some (but not all) of the yearly entries also list it as having a centerboard.

The Mariners' Museum has a single photograph of *Bradford C. French* in the Captain A.J. Currie Collection. It shows the vessel at dock in Boston, February 26, 1910, and is the same photograph contained in BOEMRE's database, so no additional copy was ordered.

An entry in the *Lloyd's Register of Shipping, Returns of Vessels Totally Lost, Condemned, &C* (1916) mentions only that *Bradford C. French* was traveling from San Juan to New Orleans with a cargo of molasses when it wrecked 60 mi (97 km) east of South Pass, Mississippi, on July 5, 1916.

Finally, the wreck is mentioned briefly in the "Marine Mishaps" section of the July 15, 1916 issue of *Lloyd's Shipping Illustrated* (1916a). Another section of the same issue describes some of the damage to Mobile, Pensacola, and parts of the Mississippi coast resulting from the hurricane that also sank *Bradford C. French* (1916b). An article in the July 22 issue of *Lloyd's Shipping Illustrated* (1916c), though it doesn't mention *Bradford C. French* by name, goes into greater detail about the extent of hurricane damage at Mobile. Specifically, as a result of the 125 miles per hour (mph) (55.9 meters per second [m/s]) winds, 10 vessels were lost near the city, another 200 damaged, and another 10 missing. These were limited mostly to "local steam and sailing craft." At Fort Morgan, 35 miles (mi) (56 km) from Mobile proper, at the mouth of Mobile Bay, most of the 25 oceangoing vessels harbored there were severely damaged in some way, and 50 seamen lost their lives.

National Archives and Records Administration (NARA), Washington, D.C.

All documents inspected at this repository were contained within Record Group (RG) 41, including Certificates of Enrollment and Registry (Bureau of Marine Inspection and Navigation) for the years 1884 (original Enrollment), 1914 (Registry), 1915 (one Registry and one Enrollment), and 1916 (final Enrollment) (Bureau of Marine Inspection and Navigation 1884, 1914, 1915a, 1915b, 1916a, 1916b). These records duplicate most of the information contained in the *Record of American and Foreign Shipping* volumes (ABS 1884–1916), with the additional listing of numerous minority-share owners along with Jacob Phillips and Crowell & Thurlow. The 1884 enrollment documents the vessel having a square stern, while the 1914, 1915, and 1916 certificates list it having an elliptical stern, suggesting that Crowell & Thurlow had made some structural changes to the hull. All of the certificates available at NARA also list only a single deck, contradicting the information in the *Record of American and Foreign Shipping.*

NARA also has a microfilm copy of the official wreck report (Bureau of Marine Inspection and Navigation 1916a). There are two wreck reports filed, differing only in the estimated value of the lost molasses cargo ($25,000 and $50,000, respectively). Both describe the wreck location as "60 mi [97 km] East of South Pass, Mississippi." No additional information is presented beyond what is available in the other previously discussed documents.

RG41 also contains three pieces of correspondence from April 1908 between Crowell & Thurlow and the U.S. Customs Service regarding *Bradford C. French* being chartered for a sugar and molasses run to Puerto Rico, and requesting permission to enter Port Real, Crab Island (a nonrecognized port of entry) before completing the voyage to Puerto Rico. It was deemed a legitimate business request and approved by the Customs office (U.S. Customs Service 1908a, 1908b; Crowell & Thurlow 1908).

Other records checked at the National Archives that did not yield any information on *Bradford C. French* include

1. RG41: Bureau of Marine Inspection and Navigation, Steamboat Inspection Service. Card reports of Casualties and Violations Investigated, 1911–1935. Tenth District (which includes New Orleans) for July 1916–June 1917.

2. RG41: Bureau of Marine Inspection and Navigation, Steamboat Inspection Service. Annual Reports of Accidents Investigated, 1911–1937, Vol. 7.

3. RG41: Bureau of Marine Inspection and Navigation, Steamboat Inspection Service. Casualties, Inspection of Vessels, and Safety of Life at Sea. Index to Casualties and Violations, 1910–1936.

SARAH BARNES

Prior to the archival research, there was little information in the BOEMRE database on *Sarah Barnes* (BOEMRE vessel ID 558). All that was known was that in October 1843 the steamer was reportedly carrying a cargo of cotton from Galveston to New Orleans when it sprang a leak during a gale 30 mi (48 km) east of the Sabine River. While running for shore, the steamer sank in six fathoms (36 ft [11.0 m]), 8 mi (12.9 km) west of the Sabine (Lochhead 1954). Most of the crew and cargo were believed lost.

Several historic newspaper and survivor accounts have provided further details on *Sarah Barnes*'s wrecking event, but unfortunately have yielded little information on the vessel itself or its history prior to sinking.

Mariners' Museum

Two entries in the *New York Shipping and Commercial List*, from October 25 and 28, 1843, respectively, report details of the wreck and were the source for the BOEMRE database information (Lochhead 1954). The report from October 28 mentions that *Sarah Barnes* sank on September 25 "while running for shore under sail and steam." An *Illustrated London News* article from November 25, 1843, further reports that 16 of the 30 passengers and crew were lost (*Illustrated London News* 1843). This source claims that *Sarah Barnes* left Galveston for New York (not New Orleans) on October 24 (not September) and sprang a leak the next morning when 75 mi (121 km) from Galveston. Captain Frankland decided to run to the nearest shore, but by 2:30 P.M. water had reached the boiler fires and engine. The crew and passengers began to make rafts out of cotton bales, and the order was eventually given to "cast off the boat's painter." *Sarah Barnes* sank shortly thereafter at 4:45 P.M. According to the *Illustrated London News,* 18 of the 30 people aboard climbed on the rafts, while the other 12 boarded the ship's painter. Of the former, only five survived after drifting for three days; two washed ashore on Galveston Island, and three landed on Bolivar Point. Nine of the twelve in the ship's boat also survived.

Another newspaper article originates from Captain Arnet, of the schooner *Caroline*, which picked up some of the wrecked vessel's cotton (*New York Herald* 1843). However, Arnet could not provide particulars on the number of lives lost or date of the wreck.

National Archives

Unfortunately, no further information on *Sarah Barnes* could be located at the National Archives. There is no listing for the vessel in the usual steamboat references (i.e., *Merchant Steam Vessels of the United States* [Lytle and Holdcamper 1952]), and subsequently no information that could be traced through archival records, such as official number, home port, builder, etc. The only register and enrollment records housed at the Washington, D.C., branch of the National Archives that go back as far as 1843 are for the Massachusetts area, and no record of *Sarah Barnes* was contained within those volumes.

A compendium of the ship registers and enrollments of New Orleans (Work Projects Administration 1942) housed in PBS&J's library was inspected for the years 1830–1850, independent of the archival research trip. No record of *Sarah Barnes* was contained in these records either.

Newspaper Archives

A search of an online database of historic newspaper archives resulted in the discovery of six additional articles describing the wrecking of *Sarah Barnes* (*Bangor Daily Whig and Courier* 1843a, 1843b; *Galveston Daily News* 1953, 1955; *New Orleans Bee* 1843; *The Experiment* 1843). Most of these articles provide variations of redundant information that appears to be adapted from the same one or two original sources. *The Experiment* (1843) essentially reprints the report of *Caroline*'s Captain Arnet, as mentioned above, with the additional detail that the boilers may have exploded. One article from the *Bangor Daily Whig and Courier* (1843a) notes that Captain Arnet's information was told to him by a fisherman on the Sabine River, who himself had been "commissioned by the mate of the steamer to seek relief for the sufferers." A second article in the *Bangor Daily Whig and Courier* (1843b) lists the names of all passengers and crew and their fate during the tragedy.

By far the most complete, and presumably accurate, accounting of the wrecking event was provided to PBS&J by Avery Munson of *Gentlemen of Fortune.* While conducting his own shipwreck research, Mr. Munson located a detailed survivor account, printed in the October 7 edition of *The Civilian and Galveston Gazette* (1843), and signed by "The Survivors of the Yawl." This letter documents that *Sarah Barnes* left Galveston at noon on Sunday, September 24, and "at 4 o'clock P.M. discharged the Pilot, and steered E.S.E. for New Orleans." Around 1:00 the following morning, wind and seas increased substantially and continued for the next few hours. By 4:30 A.M. the vessel had sprung a leak that was outpacing two engine-operated bilge pumps that "were capable of discharging nearly one barrel of water with each stroke of the engine." The captain decided to steer towards the mouth of the Sabine, which was believed to be approximately 40 mi (64 km) north-northwest, rather than towards the closest point of land, believed to be 30 mi (48 km) away. This was done to avoid wrecking the steamer in the breakers. At 3:30 P.M. there was still no land in sight and the flooding waters had extinguished the boiler fires. The captain ordered that rafts of cotton bales and the 14-ft yawl be readied for deployment. The captain and crew were to take the rafts while the passengers rode in the yawl, but before everyone could take their positions the boat rapidly began to sink, and all aboard scrambled for the nearest vessel. Twelve persons climbed into the yawl, while the remaining nineteen passengers and crew climbed aboard the cotton rafts.

The yawl quickly got separated from the rafts and steered west-northwest for the Sabine entrance, using a makeshift sail. After sailing for approximately 17 hours the yawl passengers spotted houses on shore, which they believed to mark the entrance to the Sabine. They attempted to run ashore, but the yawl was flipped in the breakers while still about a mile from dry land. The survivors tried to cling to the overturned yawl, but most were eventually separated and forced to tread water until they drifted ashore. Three of the nine passengers did not survive the swim. The rest discovered they had in fact landed 30 mi (48.3 km) west of the Sabine. From calculations of their speed and direction of travel, the survivors estimate that *Sarah Barnes* wrecked "30 or 40 mi from land, a little to the eastward of the Sabine."

HAMLET

According to the BOEMRE database, *Hamlet* (BOEMRE Vessel ID 553) reportedly ran "on to one of the Chandeleur Islands about 30 mi (48 km) from NE pass of Mississippi River" while en route from Rio de Janeiro to New Orleans on January 1, 1846. It was carrying 6,100 bags of coffee, 800 of which were thrown overboard. Six hundred bags were saved, while the rest took on water in the hold, swelled, and burst out the ship timbers (Lochhead 1954). No other descriptive information was listed in the BOEMRE database.

Smithsonian

A vessel file for *Hamlet* exists in the Maritime History records of the Smithsonian Museum of American History. According to these records *Hamlet* was a 204-ton brig built by John Dunlop of Brunswick, Maine, in 1804. It was 82 ft (25.0 m) long by 24 ft (7.3 m) abeam, with a 12-ft (3.7-m) depth of hold, and hailed out of Bath, Maine (Fairburn 1945–1955a). It is unclear whether this is the same *Hamlet* suspected to have wrecked on the Chandeleur Islands.

ORIENT

According to the BOEMRE database, *Orient* (BOEMRE Vessel ID 488), owned by Silas Weeks of New Orleans, broke apart in a hurricane 60 mi (97 km) southwest of Port Eads on September 9, 1882.

Smithsonian

The vessel files at the Smithsonian list a steamboat *Orient*, 1,560 tons, built in Portsmouth, New Hampshire, in 1852. It was 201 ft (61.3 m) long by 41 ft (12.5 m) abeam with a 20-ft (6.1-m) depth of hold, and served in the New York-Liverpool Dramatic Line from 1853–1867 (Fairburn 1945–1955b). Again, it is unknown whether this is the same vessel that later wrecked in the Gulf of Mexico and is documented in the BOEMRE database.

LITERATURE CITED

American Bureau of Shipping (ABS). 1884–1916. Record of American and foreign shipping. New York, NY.

Bangor [ME] *Daily Whig and Courier*. 1843a. "Loss of the Texan Steamer Sarah Barnes." October 30.

———. 1843b. "Sixteen lives lost – destruction of the Steamer Sarah Barnes." November 3.

Bureau of Marine Inspection and Navigation. 1884. *Bradford C. French*, Official No. 3282, Certificate of Enrollment. RG41, Official Number Files 1867–1958, National Archives, Washington, DC.

———. 1914. *Bradford C. French*, Official No. 3282, Certificate of Registry. Record Group 41, Official Number Files 1867–1958, National Archives, Washington, DC.

———. 1915a. *Bradford C. French*, Official No. 3282, Certificate of Registry. Record Group 41, Official Number Files 1867–1958, National Archives, Washington, DC.

———. 1915b. *Bradford C. French*, Official No. 3282, Certificate of Enrollment. Record Group 41, Official Number Files 1867–1958, National Archives, Washington, DC.

———. 1916a. Wreck Report, *Bradford C. French.* RG41, Microfilm roll T925, Record 85. National Archives, Washington, DC.

———. 1916b. *Bradford C. French*, Official No. 3282, Certificate of Enrollment. RG41, Official Number Files 1867–1958, National Archives, Washington, DC.

Church, R.A. and D.J. Warren. 2008. Viosca knoll wreck: discovery and investigation of an early nineteenth-century wooden sailing vessel in 2,000 feet of water. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2008-018.

Crowell & Thurlow. 1908. Letter to Commissioner of Navigation. April 21, 1908. RG41, Bureau of Navigation Correspondence 1884-1934. National Archives, Washington, DC.

Fairburn, W.A. 1945–1955a. *Merchant Sail.* Volume 5 of 6, pp. 3180, 3301. Center Lovell, ME: Fairburn Marine Educational Foundation, Inc.

———. 1945–1955b. *Merchant Sail.* Volume 2 of 6, pp. 1185, 1195, 1222, 3094. Center Lovell, ME: Fairburn Marine Educational Foundation, Inc.

Galveston [TX] *Daily News.* 1953. “Shipwrecks in Local Waters.” May 31, Section 2.

———. 1955. April 19, page 11.

Illustrated London News. 1843. November 25, pg. 338. In: Eldredge collection of steamship histories, entry: “Sarah Barnes.” Mariners’ Museum, Newport News, VA.

Lloyd’s Register of Shipping, Returns of Vessels Totally Lost, Condemned, &C. 1916. London.

Lloyd’s Shipping Illustrated. 1916a. “Marine mishaps.” July 15, LVI(715):52. New York.

———. 1916b. “The Gulf Ports.” July 15, LVI(715):56. New York.

———. 1916c. “Hurricane at Mobile.” July 22, p. 86. New York.

Lochhead, J.L. 1954. Disasters to American vessels, sail and steam, 1841–1846. Compiled from the New York Shipping and Commercial List. Mariners’ Museum, Newport News, VA.

Lytle, W.M. and F.R. Holdcamper. 1952. Merchant steam vessels of the United States 1790–1868. Staten Island, NY: The Steamship Historical Society of America, Inc. *New Orleans Bee.* 1843. “Marine intelligence.” October 16.

New York Herald. 1843. “Loss of the Steamer Sarah Barnes.” October 25, 1843. Microfilm collection at the Mariners’ Museum, Newport News, VA.

The Civilian and Galveston Gazette. 1843. “Loss of the Sarah Barnes.” October 1.

The Experiment [Norwalk, OH]. 1843. “Appalling loss of life – destruction of the New Orleans and Texas Packet Steamer Sarah Barnes.” November 8.

U.S. Customs Service. 1908a. Letter from Collector of Customs to Commissioner of Navigation. April 21, 1908. RG41, Bureau of Navigation Correspondence 1884–1934. National Archives, Washington, DC.

———. 1908b. Letter from Commissioner of Navigation to Collector of Customs. April 23, 1908. RG41, Bureau of Navigation Correspondence 1884–1934. National Archives, Washington, DC.

Work Projects Administration. 1942. Ship registers and enrollments of New Orleans, Louisiana. Volumes III and IV. Prepared by the Survey of Federal Archives in Louisiana, Service Division, Work Projects Administration. Hill Memorial Library, Louisiana State University, Baton Rouge, LA.

Appendix C

New York Artifacts

APPENDIX C: *NEW YORK* ARTIFACTS

In 2008, following completion of the remote-sensing and diver investigations, multiple correspondences between the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), *Gentlemen of Fortune*, and PBS&J, confirmed that *Gentlemen of Fortune* had recovered a sizeable amount of *New York*'s artifact assemblage. At *Gentlemen of Fortune*'s invitation, BOEMRE issued a contract modification authorizing PBS&J to visit the salvage group's facilities in New Iberia, Louisiana, for the purpose of compiling a preliminary inventory and catalog of the artifacts collected in the belief that the public was better served by preserving a record of this material than by simply allowing it to pass undocumented into private hands. BOEMRE, which has no legal jurisdiction over the site, met with *Gentlemen of Fortune* to encourage them to donate the recovered artifacts to an appropriate museum. PBS&J met with *Gentlemen of Fortune* on December 2–4, 2008. Fieldwork tasks included photo-documentation of a portion of the total collection as a means to capture singular artifact types as well as collective groups of objects. Photography encompassed multiple views of the artifacts (both obverse and reverse faces of some artifacts) as well as detailed images of maker and ownership marks. A photolog was kept, detailing the chronology of photography. A field catalog was created in which a quick sketch of an artifact was rendered and included pertinent information about each object such as basic dimensions, material, and provenience. For the vast majority of recorded artifacts, both a photograph and measured sketch were collected; however, in a few instances, only one of the two image types could be documented.

As suspected, the artifact collection was substantial. Over the span of three days, PBS&J reviewed and documented a total of 538 items within 154 artifact lots. Lot numbers were inherited from the preliminary catalog system that had already been implemented by *Gentlemen of Fortune*. In most cases, a lot number was assigned to an individual artifact (example, Artifact No. 1: glass wine bottle), but in some instances a lot number comprised multiple examples of an artifact type or separate components of a complex object (example, Artifact No. 69: 14 buttons; Artifact No. 86: pocket watch in 13 pieces). Artifact classes include ship-related mechanical items such as copper pipes and a hand pump (Nos. 110 and 105), lanterns (No. 100), and the capstan (No. 104); the ship's "hospitality" items such as ginger beer and wine bottles (multiple Nos.), silverware engraved "Steamship *New York*" (No. 84); dinnerware fragments with a printed inlay of the eagle of Texas flying over *New York* (No. 96); and personal effects such as a leather shoe (No. 82), toothbrushes (Nos. 74 and 75), and pocketknives (No. 63).

Gentlemen of Fortune assigned 120 unique lot numbers (Nos. 1–120) to the artifact assemblage, identifying artifacts with a known provenience. Items with a known provenience represented the minority of artifacts in the collection. PBS&J reviewed and assigned nonprovenienced (NP) artifact lot numbers (as time allowed) to an additional 34 artifacts, or artifact groups, for which provenience information was not recorded. In many cases, these NP numbers reflected large collections of a certain artifact type, and only a representative sample was cataloged (example, NP-5: copper sheathing). In actuality, the total number of individual nonprovenienced artifacts numbered in the thousands including, but not limited to, multiple examples of glass and ceramic sherds, miscellaneous copper pipes and valves, coal, bricks, and fasteners. Due to time constraints and the enormity of the collection, the majority of these bulk-stored items were not cataloged.

PBS&J also did not catalog *Gentlemen of Fortune*'s collection of gold, silver, and copper coins from *New York*. Though some of the coins were still housed at *Gentlemen of Fortune*'s facility, the bulk of their collection was conserved and graded at the Numismatic Conservation Service of Sarasota, Florida, and then auctioned through Stack's numismatic auction house on July 27, 2008 (Stacks

2008). The majority of these coins were discovered in the broken section of hull, forward of the engine machinery, in what *Gentlemen of Fortune* believe was the remains of the ship's safe due to the surrounding concretion of iron stains, hinges, and a large brass key (No. 65). The total collection numbered slightly over 400 gold coins and over 2,000 silver pieces. The best two examples of each variety of U.S. gold coins (if more than two existed) were auctioned off, plus a representative sample of world coins and some silver. According to numismatists, this collection included many coins that "are highly significant . . . and especially important representatives of their respective varieties" (Bowers 2008:71).

The 2008 auction included:

> U.S. gold coins: 16 Quarter Eagles (dating between 1836 and 1846), 54 Half Eagles (1834–1845), 14 Eagles (1842–1845), and a privately minted Christopher Bechtler $5 coin (1834)
>
> U.S. copper and silver: one 1-cent piece (1843), two dimes (1838–1841), two quarters (1834–1842), 29 half dollars (1795–1844), and one silver dollar (1795)
>
> "Gold coins of the world" from Chile, Columbia, Denmark, France, German States (Brunswick-Wolfenbüttel, Hannover, Prussia, Saxony), Great Britain, Sardinia, Mexico, The Netherlands, and Spain (total date range 1786–1844)
>
> "Silver coins of the world" from Central American Republic, France, Guatemala, Mexico, Peru, and Spain (total date range 1721–1846).

In July 2009 an additional 74 coins were auctioned at Stack's, plus 51 separate artifact lots (Stacks 2010). These artifact lots included several of the ginger beer bottles and silverware cataloged by PBS&J, and groupings of small artifacts (e.g. coins, nails, buttons, rings, etc.) encased in Lucite.

PBS&J's artifact catalog is presented on the following pages. Each catalog entry includes the Artifact Lot or NP number, the best photographic image (if available), artifact material and description, and, when applicable, *Gentlemen of Fortune*'s recorded provenience, which correlates to a 20-x-20-foot (ft) (6.1-x-6.1-meter [m]) grid overlaid on the site map (Figure C-1). The grid has been adjusted to conform to PBS&J's site map. Artifact lot No. 119 (the ship's boiler, still submerged in grid A-12) and No. 120 (mercury recovered from grid F-12) are not included in the catalog. Additional photographs of each cataloged artifact and some artifacts not included in the catalog are on file with PBS&J and BOEMRE.

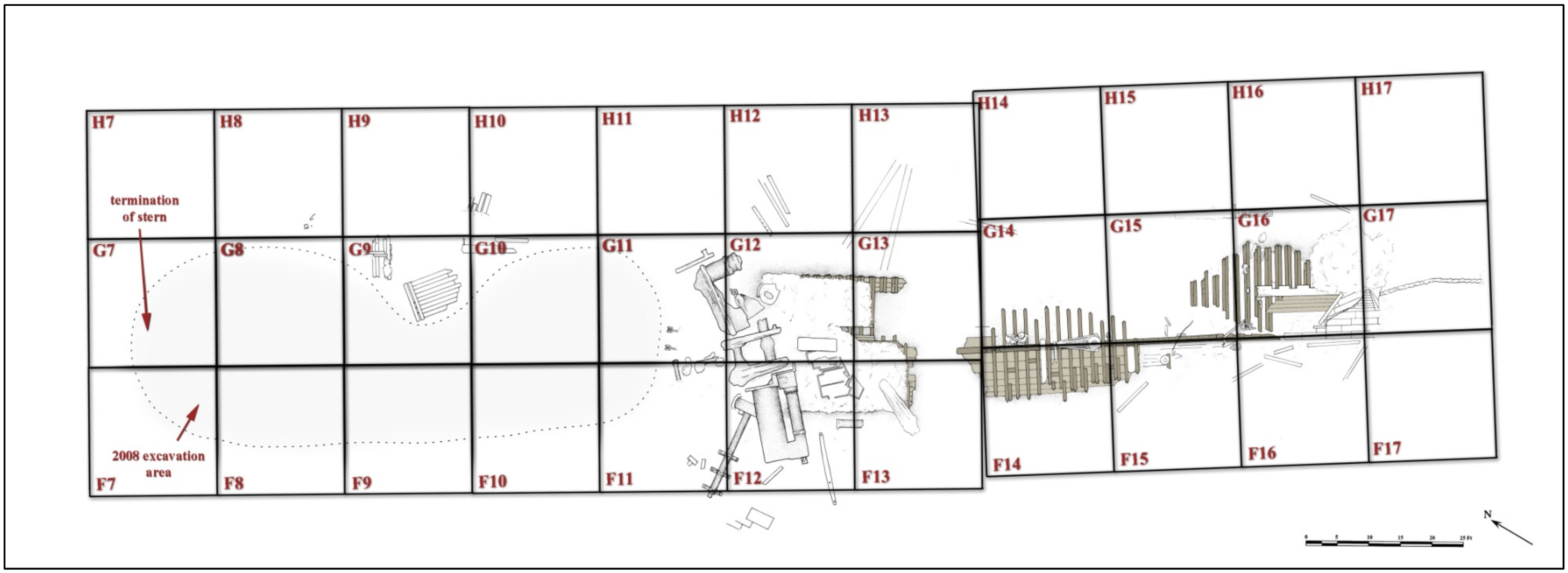


Figure C-1. New York site plan with artifact provenience grid.

LITERATURE CITED

Bowers, Q.D. 2008. The treasure ship S.S. *New York*, her story, 1837–1846. Stacks LLC, New York, NY.

Stacks. 2008. The collection of Samuel J. Berngard & treasure coins of the S.S. *New York*. Auction catalog. Stacks, LLC, New York, NY.

———. 2010. "Treasures from the S.S. New York and other important properties." Internet website: http://www.stacks.com/auctions/detail.aspx?lsid=AN00000706. March 17.

No.: 1	Material: glass
Quantity: 1	Location: H 13
Object: wine bottle	
Notes: Length is 12.25 in; diameter of base is 2.9 in; diameter of body near shoulder is 3.50 in; diameter of neck is 1.05 in; rim diameter 1.25 in.	

No.: 2	Material: glass
Quantity: 1	Location: G 15
Object: bottle	
Notes: Length is 8.75 in; diameter of body is 2.71 in; diameter of base is 2.60 in; diameter of neck varies from 0.90 to 1.24 in; rim diameter is 1.15 in.	

No.: 3	Material: coarse earthenware
Quantity: 1	Location: G 15
Object: ginger bottle	
Notes: Length 6.81 in, 2.80 in base diameter, 2.96 in shoulder diameter, 1.26 in neck diameter, 1.61 in rim diameter. Stamped "J.A. BROWN."	

No.: 4	Material: coarse earthenware
Quantity: 1	Location: F 10
Object: ginger bottle	
Notes: Dimensions not recorded. Concreted to the bell, no. 108.	

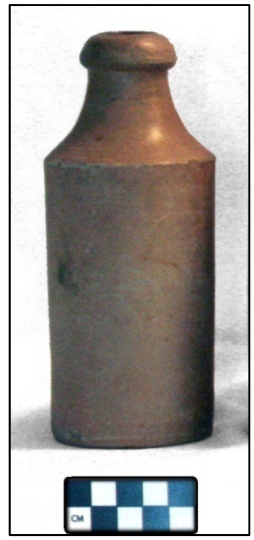
No.:	5	Material:	coarse earthenware
Quantity:	1	Location:	G 15
Object: ginger bottle			
Notes: Dimensions not recorded.			

No.:	6	Material:	coarse earthenware
Quantity:	1	Location:	G 15
Object: ginger bottle			
Notes: Dimensions not recorded. Broken – missing upper portion.			

No.:	7	Material:	glass
Quantity:	1	Location:	F 13
Object: bottle			
Notes: Diameter of base is 2.52 in; diameter of rim is 1.64 in; widest part of body has a diameter of 3.12 in; length is approximately 5.5 in.			

No.:	8	Material:	glass
Quantity:	1	Location:	F 15
Object: mineral water bottle			
Notes: Measurements not recorded. Embossed with label "F.A. CONANTS SODA OR MINERAL WATERS 252 GIROD ST. NEW ORLEANS"; reverse is embossed with a large "C."			

No.: 9	Material: coarse earthenware
Quantity: 1	Location: F 15
Object: ginger bottle	
Notes: Length 7.06 in, base diameter 2.78 in, shoulder diameter 2.93 in, neck diameter 1.25 in, rim diameter 1.60 in. Stamped "J.A. BROWN."	



No.: 10	Material: coarse earthenware
Quantity: 1	Location: F 15
Object: ginger bottle	
Note: Dimensions not recorded	

No.: 11	Material: coarse earthenware
Quantity: 1	Location: F 14
Object: ginger bottle	
Notes: Dimensions not recorded.	

No.: 12	Material: coarse earthenware
Quantity: 1	Location: G 15
Object: ginger bottle	
Notes: dimensions not recorded	

No.: 13	Material: coarse earthenware
Quantity: 1	Location: G 15
Object: wine bottle	
Notes: dimensions not recorded, Marked "Vitreous Stone Bottles Warranted not to Absorb Denby & Co. OR-PARK POTTERIES Near Dilby (?)"	

No.: 14	Material: glass
Quantity: 1	Location: F 15
Object: mineral water bottle	
Conant's mineral water bottle. Measurements not recorded. Embossed with label "F.A. CONANTS SODA OR MINERAL WATERS 252 GIROD ST. NEW ORLEANS"; opposite face is embossed with a large "C"	

No.: 15	Material: coarse earthenware
Quantity: 1	Location: F 15
Object: ginger bottle	
Notes: Dimensions not recorded.	

No.: 16	Material: glass
Quantity: 1	Location: F 15
Object: mineral water bottle	
Notes: Conant's mineral water bottle. Measurements not recorded. Embossed with label "F.A. CONANTS SODA OR MINERAL WATERS 252 GIROD ST. NEW ORLEANS"; opposite face is embossed with a large "C."	

No.: 17	Material: glass
Quantity: 1	Location: F 15
Object: mineral water bottle	

Notes: Conant’s mineral water bottle. Measurements not recorded. Embossed with label "F.A. CONANTS SODA OR MINERAL WATERS 252 GIROD ST. NEW ORLEANS"; opposite face is embossed with a large "C."

No.: 18	Material: glass
Quantity: 1	Location: F 15
Object: mineral water bottle	

Conant’s mineral water bottle. Measurements not recorded. Embossed with label "F.A. CONANTS SODA OR MINERAL WATERS 252 GIROD ST. NEW ORLEANS"; opposite face is embossed with a large "C."

No.: 19	Material: coarse earthenware
Quantity: 1	Location: F 15
Object: ginger bottle	

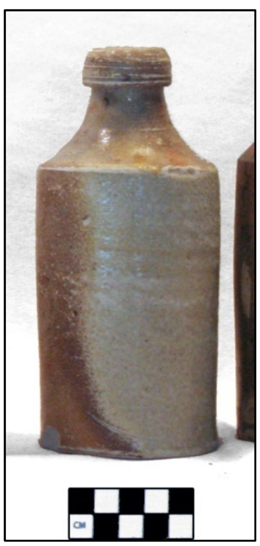
Notes: Dimensions not recorded.

No.: 20	Material: glass
Quantity: 1	Location: G 15
Object: mineral water bottle	

Notes: Conant’s mineral water bottle. Measurements not recorded. Embossed with label "F.A. CONANTS SODA OR MINERAL WATERS 252 GIROD ST. NEW ORLEANS"; opposite face is embossed with a large "C."

No.: 21	Material: glass
Quantity: 1	Location: G 15
Object: mineral water bottle	
Notes: Broken mineral water bottle. Measurements not recorded. Embossed with label "F.A. CONANTS SODA OR MINERAL WATERS 252 GIROD ST. NEW ORLEANS"; opposite face is embossed with a large "C"	

No.: 22	Material: glass
Quantity: 1	Location: G 15
Object: mineral water bottle	
Notes: Conant's mineral water bottle. Measurements not recorded. Embossed with label "F.A. CONANTS SODA OR MINERAL WATERS 252 GIROD ST. NEW ORLEANS"; opposite face is embossed with a large "C."	



No.: 23	Material: coarse earthenware
Quantity: 1	Location: H 15
Object: ginger bottle	
Notes: Dimensions not recorded.	

No.: 24	Material: coarse earthenware
Quantity: 1	Location: G 15
Object: ginger bottle	
Notes: 6 5/8 in length; 2.67 in diameter; neck diameter is 1.19 in; rim diameter is 1.47 in.	

No.: 25	Material: coarse earthenware
Quantity: 1	Location: G 15
Object: ginger bottle	
Note: Dimensions not recorded.	

No.: 26	Material: coarse earthenware
Quantity: 1	Location: G 16
Object: ginger bottle	
Note: Dimensions not recorded.	

No.: 27	Material: glass
Quantity: 1	Location: F 15
Object: mineral water bottle	
Notes: Broken mineral bottle. Measurements not recorded. Embossed with label "F.A. CONANTS SODA OR MINERAL WATERS 252 GIROD ST. NEW ORLEANS"; reverse is embossed with a large "C."	

No.: 28	Material: glass
Quantity: 1	Location: F 15
Object: mineral water bottle	
Notes: length 7.38, base diameter is 2.45, rim diameter is 1.19 in. Embossed with label "F.A. CONANTS SODA OR MINERAL WATERS 252 GIROD ST. NEW ORLEANS"; opposite face is embossed with a large "C."	

No.: 29	Material: coarse earthenware
Quantity: 1	Location: F 15
Object: ginger bottle	
Notes: dimensions not recorded. Bottle has its cork.	

No.: 30	Material: glass
Quantity: 1	Location: G 15
Object: mineral water bottle	
Notes: Complete bottle with cork. Measurements not recorded. Embossed with label "F.A. CONANTS SODA OR MINERAL WATERS 252 GIROD ST. NEW ORLEANS"; opposite face is embossed with a large "C."	

no photo

No.: 31	Material: glass
Quantity: 1	Location: G 15
Object: mineral water bottle	
Notes: Artifact not reviewed or photo-documented.	

No.: 32	Material: glass
Quantity: 1	Location: G 15
Object: mineral water bottle	
Notes: Broken mineral bottle. Measurements not recorded. Embossed with label "F.A. CONANTS SODA OR MINERAL WATERS 252 GIROD ST. NEW ORLEANS"; reverse is embossed with a large "C."	

No.: 33	Material: copper alloy
Quantity: 1	Location: G 12
Object: unknown ornamental device	
Notes: Unknown association – seems to be missing lower part of object; overall length is 12.5 in; diameter of base is 1.85 in; diameter of central "globe" device is 3.9 in.	

No.: 34	Material: glass
Quantity: 2	Location: H 10
Object: bottle and stopper	
Notes: Bottle length is 2.61 in; bottle diameter is 1.41 in; rim diameter is 0.81 in. The bottle is marked "2 oz & 44 yrs." It is scratched into the glass.	

No.: 35	Material: glass
Quantity: 1	Location: F 10
Object: wine bottle with concretion	
Notes: Length is 11.6 in; diameter of body near shoulder is 3.2 in; diameter of neck is 1.15 in; diameter of base is 2.65 in.	

No.: 36	Material: glass
Quantity: 1	Location: F 15
Object: mineral water bottle	
Notes: Conant's mineral bottle. Measurements not recorded. Embossed with label "F.A. CONANTS SODA OR MINERAL WATERS 252 GIROD ST. NEW ORLEANS"; reverse is embossed with a large "C."	

No.: 37	Material: glass
Quantity: 1	Location: F 10

Object: French ink bottle

Notes: Incomplete and broken at rim. Length is 2.32 in. square cross section, side measures 1.2 in across; neck diameter is 0.75 in. bottle embossed with mark "Perine Guyot & Cie."

No.: 38	Material: glass
Quantity: 1	Location: F 11

Object: bottle stopper

Notes: Length 2.39 in; maximum width is 0.86 in. Diameter of stopper end is 0.49 in.

No.: 39	Material: glass
Quantity: 1	Location: F 11

Object: bottle stopper

Notes: Length 2.70 in; maximum width is 0.85 in.

no photo

No.: 40	Material: coarse earthenware
Quantity: 3	Location: G 15

Object: concreted bottles

Notes: Artifact not reviewed or photo documented.

no photo

No.: 41	Material: Glass and unknown
Quantity: 1	Location: G 15
Object: bottle neck and concretion	
Notes: Artifact not reviewed or photo-documented.	

No.: 42	Material: glass
Quantity: 1	Location: G 11
Object: prism	
Notes: Heavy opaque rectangular glass base with prism top, 9.10 x 2.30 in.	

No.: 43	Material: earthenware
Quantity: 1	Location: G 10
Object: container lid	
Notes: Artifact photo-documented. Measurements not recorded.	

No.: 44	Material: coarse earthenware
Quantity: 3	Location: G 15
Object: ginger bottles and concretion	
Notes: 2 bottles – one glazed, one without glaze finish. Unglazed bottle is 6 11/16 in length, 2.78 in diameter, 1.46 in rim diameter; glazed bottle is 6 11/16 in length, 2.74 in diameter, rim diameter 1.37 in.	

no photo

No.: 45	Material: Glass and unknown
Quantity: 1	Location: G 14

Object: mineral water bottle

Notes: Artifact not reviewed or photo-documented.

No.: 46	Material: copper alloy?
Quantity: 1	Location: G 13

Object: spigot

Notes: dimensions not recorded.

no photo

No.: 47	Material: copper alloy
Quantity: 1	Location: G 7

Object: draft mark

Notes: Artifact not reviewed or photo-documented.

no photo

No.: 48	Material: unknown
Quantity: 3	Location: G 11

Object: candle base

Notes: Artifact not reviewed or photo-documented.

No.:	49	Material:	copper alloy
Quantity:	1	Location:	G 10
Object: door hardware			
Notes: 3.65 x 3.49 in.			

No.:	50	Material:	copper alloy
Quantity:	1	Location:	G 10
Object: bell			
Notes: Does not have clapper or handle. Base diameter 5.80 in. Length is 4 7/16 in.			

No.:	51	Material:	wood and lead
Quantity:	1	Location:	F 13
Object: wax stamp			
Notes: Single wax stamp in two pieces. Handle is 1.79 in long, stamp face measures 1.98 x 1.08 in, vertical slot in center of stamp.			

No.:	52	Material:	copper alloy
Quantity:	1	Location:	F 13
Object: spigot			
Notes: Overall dimensions are 3.30 x 4.50 in.			

No.:	53	Material:	copper alloy
Quantity:	1	Location:	G 10
Object: unknown			
Notes: Length is 4.37 in; width is 2.02 in.; thickness varies from 0.38 to 0.45 in.			

No.:	54	Material:	copper alloy
Quantity:	1	Location:	F 10
Object: concreted buckle			
Notes: Artifact photo-documented. Measurements not recorded.			

No.:	55	Material:	copper alloy
Quantity:	1	Location:	F 10
Object: key hole			
Notes: Length is 1.91 in, width is 1.41 in, thickness is 0.07 in.			

No.:	56	Material:	pewter
Quantity:	1	Location:	G 10
Object: candlestick			
Notes: Height of object is 3.98 in; base diameter is 5.50 in.			

No.: 57	Material: copper alloy
Quantity: 1	Location: G 13
Object: hasp	
Notes: Hinged hasp. Dimensions are 6.1 x 1.5 in.	

No.: 58	Material: Copper alloy
Quantity: 1	Location: F 10
Object: unknown	
Notes: Length is 3.66 in, width at connection point is 1.54 in. Thickness is 0.086 in.	

No.: 59	Material: copper alloy
Quantity: 1	Location: F 13
Object: spigot	
Notes: Artifact photo-documented. Measurements not recorded.	

no photo

No.: 60	Material:
Quantity: 1	Location: F 11
Object: lamp base	
Notes: Artifact not reviewed or photo-documented.	

no photo

No.: 61	Material: copper alloy
Quantity: 1	Location: F 9

Object: door latch mechanism

Notes: Artifact not reviewed or photo-documented.

No.: 62	Material: copper alloy
Quantity: 3	Location: F 10

Object: scale

Notes: Stamped “Salter’s Improved Spring Balance” “Warranted.” Measures 6.25 x 1.64 in, 0.06 in thick. Scale is measure in increments of 4 lbs.

No.: 63	Material: various
Quantity: 4	Location: G 13

Object: pocketknives and straight razor

Notes: Bone and cuprous pocketknife has length of 3.43 in; pocketknife with missing handles has length of 3.64 in; “cap” end of pocketknife is 0.71 in wide; straight razor is 4.80 in long.

No.: 64	Material: copper alloy
Quantity: 8	Location: G 13

Object: door or drawer hardware

Notes: 2 oblong keyholes with 1 keyhole cover: keyholes are 2.55 x 0.90 in and 2.52 x 0.91 in, keyhole cover is 2.41 in long; flat keyhole cover 1.91 x 0.91 in; oval keyhole 1.36 x 1.02 in; circular keyhole 0.94 in diameter; oval tapered keyhole 1.58 x 0.55 in; door latch 3.58 in long.

No.: 65	Material: copper alloy
Quantity: 1	Location: G 11
Object: key	
Notes: Length 3.46 in, maximum diameter of shank 0.37 in. Key is stamped 1162.	

No.: 66	Material: copper alloy
Quantity: 12	Location: G 9
Object: rivets or braids	
Notes: Artifact photo-documented. Measurements not recorded.	

No.: 67	Material: copper alloy
Quantity: 1	Location: G 13
Object: watch chain	
Notes: Artifact photo-documented. Measurements not recorded.	

No.: 68	Material: copper alloy
Quantity: 49	Location: F & G 8,9, 10
Object: “drapery” rings	
Notes: Artifact photo-documented. Measurements not recorded.	

No.: 69	Material: various
Quantity: 14	Location: F 10, F 13 G 13
Object: buttons	
Notes: Dimensions not recorded. Copper alloy button back is stamped "JML & WH SCOVILLE" "WATERBURY" EXTRA SUPERFINE."	

No.: 70	Material: copper alloy/iron
Quantity: 1	Location: F 11
Object: padlock	
Notes: Padlock body measures 2.54 x 2.59 in. Internal pieces are heavily corroded and appear to be of iron.	

No.: 71	Material: copper alloy
Quantity: 2	Location: F 9
Object: keys	
Notes: Larger key is 3.90 in long with maximum shank diameter of 0.26 in; small key is 2.18 in long with maximum shank diameter of 0.23 in.	

No.: 72	Material: silver
Quantity: 1	Location: G 11
Object: tongs	
Notes: 6.6 in long. Maker's mark stamped within a rectangular "cartouche" on inside surface "LELLOND DURANDE" There could be an additional letter ending the last name - this portion of the mark is illegible. Small symbols are stamped within cartouches on the other tong handle as well.	

No.: 73	Material: copper alloy
Quantity: 9	Location: G 10
Object: door latch	
Notes: 6 component parts and 3 turn screws. Cover measures 2.78 x 2.32 in. Stamped "LEWIS McKEE & CO." TERRYSVILLE CONN" "No 12."	

No.: 74	Material: bone
Quantity: 1	Location: F 10
Object: toothbrush	
Notes: Length of 6 7/16 in. base of handle is 0.61 in wide. The "head" of the toothbrush is 0.44 in wide and 0.21 in thick. 83 holes.	

No.: 75	Material: bone
Quantity: 1	Location: F 10
Object: toothbrush	
Notes: Incomplete. Length of 4.64 in, width of base is 0.56 in.	

No.: 76	Material: Mother of pearl
Quantity: 1	Location: F 11
Object: keyhole	
Notes: 0.76 x 0.62 in.	

no photo

No.: 77	Material: unknown
Quantity: 1	Location: F 13

Object: key chain

Notes: Artifact not reviewed or photo-documented.

no photo

No.: 78	Material: copper alloy
Quantity: 1	Location: F 11

Object: straight pin

Notes: Artifact not reviewed or photo-documented.

No.: 79	Material: glass
Quantity: 2	Location: F 13

Object: chandelier crystals

Notes: 2 fragments. Larger fragment is 4.36 long and 0.87 wide. Smaller fragment is 1.77 in long and 0.85 in wide.

No.: 80	Material: various
Quantity: 3	Location: F 11

Object: wax seal stamp, pocketknife fragment, and unknown

Notes: Wood-handled stamp is broken into two pieces, stamp itself is copper alloy. Broken wood handle to a pocketknife. The interior surface of the third item is threaded; the object function is unknown.

No.:	81	Material:	Wood and lead
Quantity:	1	Location:	F 11

Object: stamp

Notes: Overall length is 2.0 in, base measures 0.63 x 1.98 in. vertical slot in center of stamp. Side of stamp is marked "Bennet (or Dennet) &. CO."

No.:	82	Material:	leather
Quantity:	1	Location:	F 10

Object: shoe

Notes: Ten 12/16 in in length, greatest width is 3.87 in; heel dimensions are 2.80 x 2.14 in height of heel is 1.5 in. The heel was attached with 6 fasteners. Toe width is 2.81 in. There is no evidence of buckles or other lacing closures.

no photo

No.:	83	Material:	unknown
Quantity:	NA	Location:	NA

Object: miscellaneous parts

Notes: Artifacts not reviewed or photo-documented.

See next page

No.:	84	Material:	Silver and various
Quantity:	?	Location:	G 10

Object: silverware

Notes: 16 large silver spoons. 8.6 in long. Handles engraved "Steam Packet New York." Reverse stamped "J.L. Moore" within rectangular cartouche. One large spoon is "brassy" in coloration and is not engraved. The reverse is stamped with three small symbols, each within a square cartouche. These symbols are followed by letters "T," "&," "D," each also within a square cartouche. 19 small silver spoons are approximately 6 in long. Handles engraved "Steam Packet New York." Reverse are stamped "MOORE" within a rectangular cartouche. Three small spoons are "brassy" in coloration. One example is stamped "WARRENTED GERMAN SILVER" on the reverse. The reverse of another has the name "Johnson" scratched into the surface. “Brassy” colored dinnerware is likely German silver (nickel and copper). Several are stamped as such.

Additional notes for artifact No. 84: 15 large silver forks. Most well-preserved example is 8.0 in long. Handles are engraved "Steam Packet New York." Reverse stamped "J.L. Moore" within rectangular cartouche.

Additional images for artifact No. 84: Spoons

No.: 85	Material: glass
Quantity: 1	Location: H 11

Object: bottle

Notes: Large bottle, 18 in tall with a base diameter of 7 3/8 in; rim diameter is 1.30 in, neck diameter is 1.95 in.

No.: 86	Material: Gold, cuprous
Quantity: 13	Location: F 10

Object: pocket watch

Notes: Outer diameter of casing is 2.17 in; diameter of watch face is 1.68 in. Internal mechanism stamped "RT Watson & Co 1400 Liverpool Patent." Reverse of watch face is hand-inscribed "$250" "James Sutton (or Lutton-slightly illegible)"; interior of watch casing stamped "B&B" "1400" with three impressed symbols.

No.: 87	Material: bone
Quantity: 1	Location: F 10

Object: syringe and plunger

Notes: Main body (excluding plunger handle) is 3.53 in long, 0.42 in diameter.

No.: 88	Material: glass
Quantity: 1	Location: F 13

Object: lighting feature?

Notes: 10.60 x 3.30 in. slightly damaged opaque glass object. Overall thickness is 1.35 in.

Additional images for artifact no. 86.

No.: 89	Material: wood
Quantity: 1	Location: F 9
Object: auger or corkscrew handle	
Notes: 3.37 in long, diameter of each is 0.86 in.	

No.: 90	Material: copper alloy
Quantity: 1	Location: G 12
Object: ornamental base	
Notes: diameter 2.86 in; height 0.92 in.	

No.: 91	Material: copper alloy
Quantity: 2	Location: G 12
Object: rail and wheel	
Notes: Rail is 14.7 in long and 1.04 in wide, the central track along the rail is 0.20 in thick and is elevated 0.30 in from the base of the rail; the wheel has a diameter of 2.51 in.	

No.: 92	Material: copper alloy
Quantity: 1	Location: G 9
Object: wheel	
Notes: Artifact photo-documented. Measurements not recorded.	

No.: 93	Material: glass
Quantity: 1	Location: G 9
Object: bottle stopper	
Notes: 2.10 x 0.90 in.	

No.: 94	Material: bottle
Quantity: 1	Location: G 10
Object: bottle	
Notes: Artifact photo-documented. Measurements not recorded.	

No.: 95	Material: glass
Quantity: 1	Location: F 9
Object: glass stem and base	
Notes: Fluted glass fragment, 4.6 in tall; base diameter is 2.6 in.	

No.: 96	Material: refined earthenware
Quantity: 3	Location: F 9
Object: unknown	
Notes: 3 fragments from a ceramic dish that is possibly hexagonal in shape. It is a representation of the eagle and the steamboat *New York*. The largest fragment measures 2.48 x 1.10 in; thickness is 0.21 in.	

No.: 97	Material: glass
Quantity: 13	Location: G 8
Object: unknown	
Notes: not measured.	

No.: 98	Material: pewter?
Quantity: 1	Location: F 10
Object: “grease gun”	
Notes: Object is broken and incomplete. Preserved length is 9.8 in; diameter of main body is 1.58 in.	

No.: 99	Material: copper alloy
Quantity: 1	Location: G 11
Object: “strainer”	
Notes: Outer diameter 9.25 in, "basket diameter" 6 in; height 1.28 in; lip is 0.07 in thick.	

No.: 100	Material: copper alloy
Quantity: 1	Location: G 15
Object: lantern	
Notes: 14 inches tall; diameter at base is 11.25 in.	

no photo

No.: 101	Material: unknown
Quantity: NA	Location: G 15
Object: bucket	
Notes: Artifact not reviewed or photo-documented.	

No.: 102	Material: Copper alloy
Quantity: 1	Location: G 11
Object:"bucket strainer"	
Notes: Intact; 11 in tall; diameter of 7.5 in. Holes at base are 9/16 in diameter then decrease to 7/16 in and 1/4 in diameters. The holes are largest at the base, decreasing in size towards the top.	

No.: 103	Material: undetermined
Quantity: 1	Location: G 11
Object: pitcher	
Notes: Height is 8.5 in; body diameter is 7 in; base diameter is 6 in; there is a strainer located inside the rim at the spout.	

No.: 104	Material: copper alloy
Quantity: 8	Location: F 15
Object: capstan	
Notes: Capstan has a diameter of 25.75 in, thickness of 5.33 in; 6 staves measuring 18 x 2.72 in; base of capstan has an outer diameter of 29.63 and a height of 7.3 in (excluding attachment bolts).	

No.: 105	Material: copper alloy
Quantity: 1	Location: G 12
Object: pump	
Notes: Diameter of shaft is 6 in.	

no photo

No.: 106	Material: unknown
Quantity: NA	Location: F & G, 11, 12
Object: various valves	
Notes: Artifact not reviewed or photo-documented.	

No.: 107	Material: stone
Quantity: 1	Location: G 10
Object: sharpening stone	
Notes: 17.5 in diameter with a 2-in-square opening in the center; 3.25 in thick.	

No.: 108	Material: copper alloy/iron
Quantity: 1	Location: F 10
Object: ship's bell	
Notes: Overall height is 19 in. Diameter of base is 18.25 in. Diameter at top of bell, above maker's name, is 9 in. Bell is marked around the top with the following, "James P Allaire New York 1833."	

no photo

No.: 109	Material: unknown
Quantity: 1	Location: H 11
Object: "sea strainer"	
Notes: Artifact not reviewed or photo-documented.	

No.: 110	Material: unknown
Quantity: NA	Location: NA
Object: various pipes and flanges	
Notes: Artifact not reviewed. Sample was photo-documented.	

No.: 111	Material: copper alloy
Quantity: NA	Location: NA
Object: nails, spikes, bolts (fasteners)	
Notes: Representative sample of 8 sheathing tacks and 2 nails. Sheathing tacks are square in cross section towards the tip and circular in diameter at the base of the head. Lengths were between 1.00 and 1.08 in, all neck diameters were 1.5. Head diameters were 0.31–0.35 in. 2 nails of roughly square cross section with rectangular heads: 2.41 in long, shank 0.20 x 0.26 in , and head 0.38 x 0.16 in ; 2.47 in long, shank 0.28 x 0.27 in, head 0.15 x 0.17 in.	

No.: 112	Material: coal
Quantity: NA	Location: NA
Object: coal	
Notes: Small sample photo-documented. Measurements not recorded.	

No.: 113	Material: brick
Quantity: NA	Location: NA
Object: brick	
Notes: Small sample photo-documented. Measurements not recorded.	

See reference: Stack's 2008

No.: 114, 115, 116	Material: various
Quantity: NA	Location: in break
Object: gold, silver, copper coins	
Notes: Artifact not reviewed or photo-documented.	

No.: 117	Material: Refined earthenware
Quantity: 1	Location: G 12
Object: dish	
Notes: Diameter of 6.5 in, height of 1.27 in. Makers mark on base is illegible.	

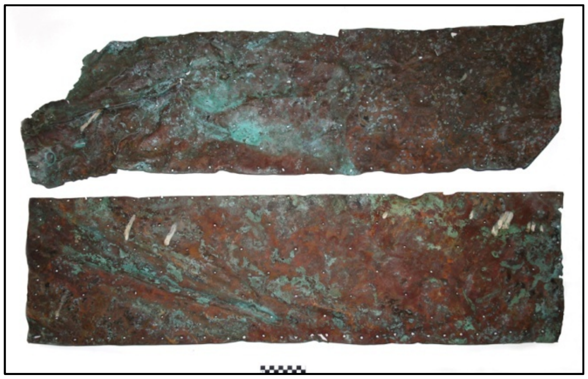
No.: 118	Material: bone
Quantity: 1	Location: F 9
Object: brush (boot?)	
Notes: 1.15 x 3.85 in.	

No.:	NP-1	Material:	Copper alloy
Quantity:	1	Location:	NA
Object: oil lamp fragment			
Notes: Preserved length is 4.14 in, diameter of main cylinder is 1.15 in, diameter of burner is 0.98 in.			

No.:	NP-2	Material:	cuprous/pewter
Quantity:	2	Location:	NA
Object: buttons			
Notes: Pewter button has 4 holes and is 0.69 in diameter; cuprous button has 0.50 in diameter.			

No.:	NP-3	Material:	Copper alloy
Quantity:	1	Location:	NA
Object: lamp part			
Notes: 5.04 length, diameter of shaft ranges from 0.71 to 0.85 in; diameter of top (maximum) is 2.20 in.			

No.:	NP-4	Material:	copper alloy
Quantity:	7	Location:	NA
Object: buckles			
Notes: 3 sizes of same basic design. Large buckle is 2.05 x 0.99 in; medium is 1.15 x 1.04 in; small is 0.60 x 0.58. there are 3 large buckles, 3 medium (one is broken), and one small buckle. Reverse of larger buckles are marked "?ARNAULT" and "BREVETE." Breveté is French for "patent."			



No.:	NP-5	Material:	Copper alloy
Quantity:	NA	Location:	NA
Object: copper sheathing			
Notes: Most complete example of the 15–20 sheets reviewed. 47.63 x 14 in, 0.05 in thickness. Fastener holes spaced 1.5 in around the perimeter of the sheet. Every third fastener was connected to a row that extended diagonally across the sheet. Fastener spacing along the diagonal was approximately 3.25 in. No visible maker's mark.			

No.:	NP-6	Material:	glass
Quantity:	3	Location:	NA
Object: mineral bottle fragments			
Notes: 3 fragments of the upper portion of the mineral bottles. Measurements not taken. Largest example has embossed letter TS (part of CONANTS).			

No.:	NP-7	Material:	glass
Quantity:	2	Location:	NA
Object: mineral bottle fragments			
Notes: 2 base fragments. Larger example is 2.53 in long and 2.54 diameter Portions of the embossed label is evident "25 (incomplete)" "NEW ORLEANS." Smaller example is 1.28 in and 2.49 diameter. "NEW OR" is visible.			

No.:	NP-8	Material:	glass
Quantity:	1	Location:	NA
Object: mineral bottle fragments			
Notes: Base fragment, 3.74 in long with 2.49 in diameter. Embossed label is broken but still legible " W(broken)RS 252 GIROD ST NEW ORLEANS."			

No.: NP-9	Material: glass
Quantity: 1	Location: NA
Object: mineral bottle fragment	
Notes: Lower portion of bottle, 3.83 in with 2.56 in diameter. Embossed "E(incomplete)" over "MINERAL WATER." Reverse face embossed with word "PATENT."	

No.: NP-10	Material: pewter
Quantity: NA	Location: NA
Object: Parts of candle holders?	
Notes: photo-documented, measurements not recorded.	

No.: NP-11	Material: leather
Quantity: 1	Location: NA
Object: unknown	
Notes: Linear leather piece that is 3 in wide. It is folded at the seam and riveted to itself.	

No.: NP-12	Material: cuprous/wood
Quantity: 1	Location: NA
Object: unknown	
Notes: Machinery part with a wooden ball within a float valve. 16.25 in long. Float housing is approximately 2 x 1.5 in. Wood ball has 1 in diameter.	

No.: NP-13	Material: copper alloy
Quantity: 1	Location: NA
Object: threaded pipe or possible hose connection	
Notes: 2.63 in long. Diameter is both 2.3 and 2.0 in.	

No.: NP-14	Material: copper alloy
Quantity: 1	Location: NA
Object: rail	
Notes: 12.13 in length, width is 1.9. Similar to artifact No. 91.	

No.: NP-15	Material: copper alloy
Quantity: 1	Location: NA
Object: keyhole	
Notes: Diameter 1.07 in, thickness 0.06 in.	

No.: NP-16	Material: coarse earthenware
Quantity: 2	Location: NA
Object: container sherds with marks	
Notes: Photo-documented, measurements not recorded.	

No.:	NP-17	Material:	Cuprous/pewter
Quantity:	6	Location:	NA
Object: buttons			
Notes: 4 identical pewter buttons of 0.69 in diameter (4 holes); cuprous button of 0.47 in diameter; cuprous button of 0.93 in diameter. 0.47 diameter cuprous button is stamped on reverse face "Burnham" and " M(illegible) CO."			

No.:	NP-18	Material:	Cuprous/wood
Quantity:	1	Location:	NA
Object: portion of wood door with doorknob			
Notes: Overall dimensions are 16.5 x 4.5 in. Lock mechanism measures 5.01 x 3.73 x 0.73 in. Exterior doorknob diameter is 1.71 in and interior doorknob diameter is 1.26 in. Wood door fragment is 16.5 in long and 1.21 in thick.			

No.:	NP-19	Material:	glass
Quantity:	8	Location:	NA
Object: stemware			
Notes: 8 stemware shards of same style of glass of two differing sizes. 1 rim and 5 bases from larger size and 2 bases from the smaller size glass. See artifact no. 95.			

No.:	NP-20	Material:	copper alloy
Quantity:	1	Location:	NA
Object: bell			
Notes: Base diameter 5.06 in; height 4.02 in. no clapper and no handle.			

No.:	NP-21	Material:	bone/unknown
Quantity:	1	Location:	NA

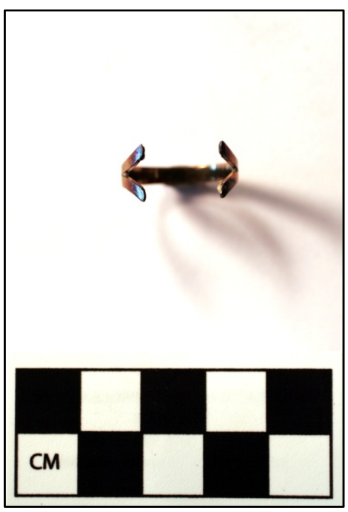
Object: dinner knife

Notes: Concreted table knife 10.5 in long. Ivory handle has square cross section of 0.72 in. Concreted blade height is 1 in. Concrete blade appears rounded at tip.

No.:	NP-22	Material:	copper alloy
Quantity:	1	Location:	NA

Object: part of deadbolt lock

Notes: 4.94 in long, 1.30 in wide.



No.:	NP-23	Material:	
Quantity:	1	Location:	NA

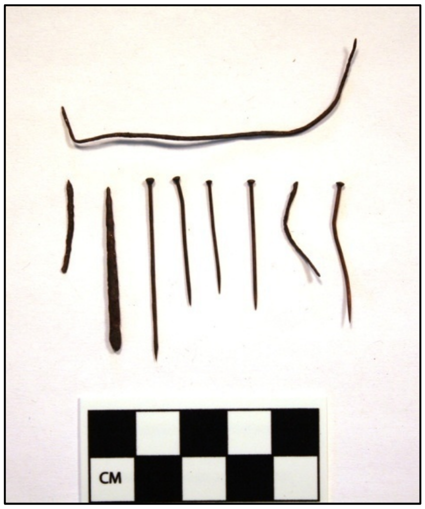
Object: ring (no setting)

Notes: 0.76 in outer diameter, inside diameter of 3 millimeters.

No.:	NP-24	Material:	bone (ivory)
Quantity:	3	Location:	NA

Object: dinner knife handles

Notes: 3 handles of two sizes. Large handle is 5.56 in long with 0.58 x ? cross section and blade end and 0.80 x ? cross section at opposite end. Cross section dimensions for the smaller handles are the same as for the larger handles - length is instead 3.86 in.



No.: NP-25	Material: copper alloy
Quantity: 9	Location: NA
Object: 5 pins and miscellaneous wire, needle?	
Notes: Pins measured between 0.95 and 1.51 inches in length.	

No.: NP-26	Material: earthenware
Quantity: 7	Location: NA
Object: sherds with marks	
Notes: Cermaic with blue-transfer mark " FANCY HARDWARE BROOKLYN,N.Y."; ceramic base stamped "7"; teacup base stamped with a small triangle and the number "29"; ceramic with an unidentifiable embossed pattern on inner surface; small sherd with female face; sherd with an unidentifable embossed pattern on outer surface; base with a partially visible blue-transfer print.	

No.: NP-27	Material: coarse earthenware
Quantity: 41	Location: NA
Object: sherds	
Notes: Variety of sherds including 3 bases and 2 rims from ginger bottles.	

No.: NP-28	Material: refined earthenware
Quantity: 46	Location: NA
Object: sherds	
Notes: variety of vessel sherds.	

No.: NP-29	Material: glass
Quantity: 17	Location: NA
Object: miscellaneous glass shards	
Notes: Glass shards that could not be categorized as wine bottle or stemware glass.	

No.: NP-30	Material: glass
Quantity: 46	Location: NA
Object: wine bottle shards	
Notes: Wine bottle shards and other similar green bottle glass fragments.	

No.: NP-31	Material: unknown
Quantity: 1	Location: NA
Object: concreted knife	
Notes: Photo-documented, measurements not recorded.	

No.: NP-32	Material: copper alloy
Quantity: 12	Location: NA
Object: rivet heads?	
Notes: Photo-documented, measurements not recorded.	

No.:	NP-33	Material:	coarse earthenware
Quantity:	2	Location:	NA
Object: body sherds			
Notes: Photo-documented, measurements not recorded.			

No.:	NP-34	Material:	coarse earthenware
Quantity:	46	Location:	NA
Object: body sherd			
Notes: Photo-documented, measurements not recorded.			

Appendix D

History of Tropical Storms Affecting Primary Study Sites

APPENDIX D: HISTORY OF TROPICAL STORMS AFFECTING PRIMARY STUDY SITES

The average time on the seabed of the four study sites is estimated to be 80–83 years. Collectively these four sites have experienced 32–33 hurricanes within a 40-mi (64-kilometer [km]) radius (U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration 2010). Prior to Katrina, *Castine* experienced at least 14 other tropical storms centered within a 40-mi (64-km) radius of the site, including six that were at hurricane strength when they passed (Table D-1). The first hurricane to pass *Castine* was in 1948, 24 years after its sinking. In the absence of hindcast data for those earlier storms, the effect of each storm on *Castine* is unknown. The two storms arguably affecting *Castine* with the greatest force were Betsy in 1965 (Category 3) and Andrew in 1992 (Category 4). Betsy passed to the east of *Castine* with the site located on the weak side of the storm, but at a distance of only 12.7 mi (20.4 km), while Andrew passed at a distance comparable to Katrina but to the west of *Castine* (with the site located on the storm's stronger side).

Table D-1

Tropical Storms Passing within 40 mi of *Castine*
(NOAA 2010)

Storm ID	Name	Storm Date	Distance (mi [km])	Wind (mph [m/s])
628	None	7/27/1936	29 (47)	46 (21)
660	None	9/26/1939	36 (58)	40 (18)
702	None	9/10/1944	34 (55)	46 (21)
719	None	6/15/1946	5 (8)	40 (18)
738*	None	9/4/1948	22 (35)	75 (33)
747	None	9/4/1949	21 (34)	46 (21)
829*	Flossy	9/24/1956	10 (16)	86 (39)
906*	Betsy	9/10/1965	13 (21)	127 (57)
1042*	Bob	7/11/1979	35 (56)	75 (33)
1105	Juan	10/31/1985	9 (15)	63 (28)
1166*	Andrew	8/26/1992	33 (53)	144 (64)
1223	Danny	7/18/1997	8 (13)	63 (28)
1291	Isidore	9/26/2002	12 (20)	63 (28)
1328*	Cindy	7/6/2005	7 (11)	75 (33)
1336*	Katrina	8/29/2005	30 (49)	138 (81)

*Indicates a storm with hurricane-force winds near its center at the time of closest passage to the site

Depending on the age of Site 323, discovered in 1994, it might have experienced as many as eight other tropical storms centered within a 40-mi (64-km) radius of the site, prior to Rita, including three that were at hurricane strength when they passed (Table D-2). In the absence of hindcast data for those earlier storms, the effect of each storm on Site 323 is unknown. The earliest hurricane likely to have affected Site 323 was Edith in 1971, followed by Danny and Juan, both in 1985. The eye of Hurricane

Juan, although only a Category 1 storm, passed approximately 1.2 mi (1.9 km) to the west of Site 323. Given the wave heights associated with Rita at a distance of 28 mi (45 km), it seems likely that Juan would have a similar, if not greater, effect on the site. If the Site 323 vessel sank after 1985, then Rita would have been the first hurricane to affect the site.

Table D-2

Tropical Storms Passing within 40 mi of Site 323
(NOAA 2010)

Storm ID	Name	Storm Date	Distance (mi [km])	Wind (mph [m/s])
961	Felice	9/15/1970	9 (15)	63 (28)
970*	Edith	9/16/1971	28 (46)	98 (44)
1053	Danielle	9/5/1980	4 (7)	46 (21)
1099*	Danny	8/15/1985	14 (22)	92 (41)
1105*	Juan	10/28/1985	2 (3)	86 (39)
1268	Allison	6/11/2001	12 (20)	35 (15)
1284	Bertha	8/7/2002	7 (11)	29 (13)
1319	Ivan	9/23/2004	9 (14)	46 (21)
1342*	Rita	9/24/2005	28 (46)	121 (54)

*Indicates a storm with hurricane force winds near its center at the time of closest passage to the site

Prior to Rita, *Gulf Tide* experienced at least 14 other tropical storms centered within a 40-mi (64-km) radius of the site, including 5 that were at hurricane strength when they passed (Table D-3). The earliest and most severe hurricane likely to have affected *Gulf Tide* was Audrey in 1957. Hurricane Audrey passed 9 mi (14 km) west of the site as a Category 4 storm. Based on a comparison with hindcast data from 11.5 mi (18.5 km) to the east of Rita's path, it seems likely that Audrey generated waves in excess of 26 feet (8 meters) over *Gulf Tide*. In the absence of hindcast data for earlier storms, the effect of each storm on *Gulf Tide* is unknown.

New York experienced at least 31 other tropical storms centered within a 40-mi (64-km) radius of the site, prior to Rita, including 15 that were at hurricane strength when they passed (Table D-4). The nearest hurricane, and therefore possibly one of the most severe, likely to have affected *New York* was an unnamed Category 1 storm (see Table D-4, Storm ID 677) that passed within 5 mi (8 km) of the site on its strong side. Hurricane Audrey passed 15 mi (24 km) west of the site as a Category 4 storm. Based on a comparison with hindcast data from 35–46 mi (56–74 km) to the right of Rita's path in similar water depths, it seems reasonable that the 1900 and 1915 Galveston storms (see Table D.4, Storm IDs 371 and 478) and a Category 4 storm in 1932 (see Table D.4, Storm ID 577) might have generated waves in excess of 26.2–29.5 ft (8.0–9.0 m) over *New York*. In the absence of hindcast data for earlier storms, the effect of each storm on *New York* is unknown.

LITERATURE CITED

U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration. 2010. Historical hurricane tracks. Internet website: http://csc-s-maps-q.csc.noaa.gov/hurricanes/download.jsp. Last accessed on May 13.

Table D-3

Tropical Storms Passing within 40 mi of *Gulf Tide*
(NOAA 2010)

Storm ID	Name	Storm Date	Distance (mi [km])	Wind (mph [m/s])
832*	Audrey	6/27/1957	9 (14)	144 (64)
833	Bertha	8/10/1957	37 (59)	69 (31)
886*	Cindy	9/17/1963	39 (62)	75 (33)
961	Felice	9/15/1970	0 (0)	63 (28)
970*	Edith	9/16/1971	9 (14)	92 (41)
1033	Debra	8/28/1978	7 (11)	52 (23)
1043	Claudette	7/24/1979	9 (15)	52 (23)
1053	Danielle	9/5/1980	9 (15)	58 (26)
1076	Chris	9/11/1982	16 (26)	58 (26)
1108*	Bonnie	6/26/1986	11 (18)	86 (39)
1134*	Chantal	8/1/1989	18 (30)	81 (36)
1268	Allison	6/10/2001	33 (53)	35 (15)
1284	Bertha	8/7/2002	31 (50)	29 (13)
1319	Ivan	9/24/2004	36 (58)	35 (15)
1342*	Rita	9/24/2005	8 (13)	115 (51)

*Indicates a storm with hurricane-force winds near its center at the time of closest passage to the site

Table D-4

Tropical Storms Passing within 40 mi of *New York*
(NOAA 2010)

Storm ID	Name	Storm Date	Distance (mi [km])	Wind (mph [m/s])
83	none	9/29/1863	37 (60)	58 (26)
109*	none	10/4/1867	17 (28)	104 (46)
174*	none	9/17/1877	31 (49)	81 (36)
195*	none	8/22/1879	19 (30)	104 (46)
241*	none	6/14/1886	26 (42)	92 (41)
356	none	9/28/1898	40 (65)	58 (26)
371*	none	9/9/1900	33 (53)	144 (64)
478*	none	8/17/1915	36 (59)	121 (54)
577*	none	8/14/1932	39 (63)	144 (64)
612	none	8/27/1934	7 (12)	69 (31)
654	none	10/17/1938	37 (60)	40 (18)
668	none	9/24/1940	26 (41)	46 (21)
671	none	9/14/1941	37 (59)	46 (21)
677*	none	8/21/1942	5 (8)	81 (36)
687*	none	7/27/1943	10 (16)	86 (39)
727*	none	8/24/1947	15 (24)	81 (36)
832*	Audrey	6/27/1957	15 (25)	144 (64)
886*	Cindy	9/17/1963	12 (20)	75 (33)
961	Felice	9/16/1970	19 (30)	69 (31)
970*	Edith	9/16/1971	15 (25)	92 (41)
989	Delia	9/4/1973	36 (58)	69 (31)
1033	Debra	8/28/1978	9 (15)	46 (21)
1043	Claudette	7/24/1979	17 (27)	52 (23)
1053	Danielle	9/5/1980	21 (34)	58 (26)
1076	Chris	9/11/1982	5 (7)	58 (26)
1108*	Bonnie	6/26/1986	15 (24)	86 (39)
1113	none	8/10/1987	25 (40)	46 (21)
1134*	Chantal	8/1/1989	7 (12)	81 (36)
1190	Dean	7/30/1995	30 (48)	40 (18)
1268	Allison	6/10/2001	25 (40)	35 (15)
1284	Bertha	8/8/2002	36 (59)	29 (13)
1342*	Rita	9/24/2005	34 (55)	115 (51)

*Indicates a storm with hurricane-force winds near its center at the time of closest passage to the site