Boston Harbor drained: a case study using hydrographic systems to assess potential cultural resource sites

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Abstract

A recent navigation project in Boston Harbor, Massachusetts illustrated the use of different hydrographic techniques in assessing cultural resources. The NOAA Ship WHITING, a hydrographic research vessel for the U.S. Department of Commerce’s, National Oceanic and Atmospheric Administration, surveyed the entire harbor and its approaches. The main goal of the project was to update the nautical charts for safe navigation. However, the hydrographic team also addressed areas of cultural significance, with particular attention paid to the inner harbor waterfront, the harbor’s islands, and shipwrecks located in the waterways. Several remote sensing techniques were used; tools and expertise that are currently being under utilized by the submerged cultural resource community. This paper does not highlight the history of Boston Harbor, but rather use it as a backdrop for how best to survey an historical harbor given the appropriate tools and proper planning. It also stresses the need for archaeological expertise in hydrographic surveying.

1 Introduction

National Oceanic and Atmospheric Administration (NOAA), under the U.S. Department of Commerce, is responsible for charting the US coastlines and ports. Analogous agencies to NOAA include the Canadian Hydrographic Service and the United Kingdom Hydrographic Office. NOAA acquires bathymetric data, processes it and creates nautical charts used by mariners throughout the world. NOAA targets major ports to frequently survey to assess
any charges in the bathymetry, or bottom features, so that charts can be updated for safe navigation. In 2000 and 2001, NOAA targeted Boston Harbor, Massachusetts as a port to be surveyed. The NOAA Ship WHITING, a 168 foot hydrographic research vessel with two survey launches, and a crew of about thirty-five men and women conducted that Boston survey.

The primary goal of the Boston Harbor project was to update the nautical charts for safe navigation, with main emphasis paid to the approaching channels and harbor waterways. The Whiting assessed changes in bathymetry, recognizing areas of shoaling from natural sedimentation processes, and discovering man-made obstructions discarded from transiting vessels. While surveying, the Whiting was also able to address areas of cultural significance, with particular attention paid to three different types of historical evidence in the area.

The first is Boston’s Inner Harbor, where the surveyed area encompassed the entire harbor all the way to the piers and bulkheads, potentially shedding light on submerged waterfront structures. The second is Rainford Island, an on-going project designed by the University of New Hampshire, which looked at the structural remains of a small island, uncovering an isolated piece of Boston’s past. Finally, individual wreck sites were examined to determine if they were dangers to navigation. New wrecksites were also preliminarily identified, measured and recorded.

It is important to note that hydrographers often pay little attention to the historical significance of items found on the bottom. Items are examined in regards to how they may or may not impede safe navigation. Archeologists or cultural resource managers (CRM) often do not actively collaborate with hydrographic teams that are working in their area. Furthermore, these groups rarely address the cultural resources uncovered within every completed hydrographic harbor survey. This paper hopes to bridge that gap by highlighting the effective tools and expertise generated by hydrographic units. Some archaeologists are already familiar with the equipment used in Boston Harbor, but they may not be aware of the professional groups that use it on a constant basis. NOAA’s hydrographic teams welcome the expertise offered by archeologists, and encourage them to get involved in survey projects and to assess hydrographic data.

2 Techniques in coastal mapping

When it comes to charting coastlines, NOAA’s primary mission is to provide the mariner with a clear understanding of the ocean bottom in regard to safe navigation. This is different from mapping areas strictly for geological or archaeological purposes. NOAA is only interested in shoalest soundings. The tools that hydrographers use need to be highly accurate since they are liable for their work. A typical harbor survey, like the one conducted in Boston, has an error budget of only about 0.1 meters. In order to obtain the most accurate least depths, areas are mapped intensively, often surveying the same region three times with at least two different instruments. What this means to the archaeologist is that an area is intensively ensonified leaving no wreck or
historical pier piling undetected. For the purposes on project planning and data acquisition, it may be important for the CRM to understand how NOAA accomplishes this.

NOAA follows the International Hydrographic Organizations standards of mapping the ocean bottom, which outlines the requirements for different coverage at different depths [1]. To be brief, this includes acquiring two 100% side scan sonar (SSS) coverage datasets, and in some case a one 100% shallow water multibeam (SWMB) bathymetry dataset. SSS data provides qualitative, imagery data of the bottom – a snapshot of what is actually down there. SWMB is qualitative, bathymetry data that provides highly precise sounding information with sub-meter accuracy, giving the harbor bottom its texture. Survey line plans are designed for each dataset, and loaded onto navigational software for the hydrographic survey vessels to follow, ensuring complete coverage.

Survey planning is different for each technology. Since SSS coverage is dependant on fixed range settings (i.e., a constant range scale of 100 meters yields a 200 meter swath coverage), uniform line spacing is used. NOAA accounts for at least 15% overlap of the outer edge of the swath, so a typical 100 meter range scale survey uses 180 meter line spacing to guarantee full bottom coverage. The second 100% SSS data is specifically designed to offset directly between the previous set of SSS lines. The two SSS datasets compensate for each other’s blind spots, and provide two independent images of any items located on the two SSS trances. This plan will work provided the SSS towfish (an instrument towed behind the vessel that transmits and received the sonar data) is “flown” off the ocean floor at a depth close to 10% of the range scale. For example, if operating at 100 meter range scale, the towfish must be near 10 meters off the bottom, but no more than 20 meters high. If the towfish altitude breaches these parameters, then the SSS data will not meet IHO standards when it is slant range corrected (depth compensated) during processing [2].

Unlike SSS, which is range scale dependent, SWMB surveying is depth dependant. For most multibeam systems, the sonar coverage is about three to five times the water depth (i.e. in 10 meters of water, the line spacing should be about 35 meters). The hydrographer usually uses existing depths on the chart as a guide to making initial line plans. Survey lines are created parallel to the depth contours so that the coverage will be even throughout the entire line, and the line spacing can evenly increase as the depth increases. If, for whatever reason, “holidays”, or data gaps, are generated, that area will need to be re-surveyed.

Boston Harbor is dotted with shoals and islands, and the bottom is inconsistent due to erratic glaciations. This makes efficient SSS and SWMB survey line planning difficult. Islands and ledges disjoint traffic channels, prohibiting long line segments. Due to the general shallowness of the harbor (less than 60 meters), SWMB line spacing was tight, and thousands of survey lines had to be created to acquire full bottom coverage. Hydrography is a production driven operation like every other business, so surveying Boston Harbor challenged even the most efficient hydrographers.

Strategically surveying an area is as much an art as it a science. Despite prior planning, it is often left to the discretions of the hydrographer acquiring the data.
to understand the bottom and water conditions to obtain the best data and most coverage [3]. During data processing, noisy data is rejected while valid data is saved, dangers to navigation are found, and gaps are flagged for further development. There are other types of data to be managed too. The accuracy of the whole operation is dependent on the ancillary data acquired throughout the survey, which includes: tidal information, sound velocity profiles, vessel motion sensors, and vessel position information. Time is the key element linking all the different forms of data together.

Once data is acquired and processed, side scan mosaics derived from the SSS data, and sun-illuminated digital terrain models from the SWMB data are created. These are the ultimate products used by hydrographers to characterize Boston Harbor. Both tools tell different stories of the harbor bottom, and cultural resource managers can gain the most information about Boston’s past. The following results highlight some of the cultural finds, and the hydrographic techniques used.

3 Uncovering the Inner Harbor

The maritime landscape of Boston Inner Harbor has dramatically changed throughout the years. Wetlands have been reclaimed, now supporting multi-story office buildings and hotels. Dilapidated fishing wharfs that once bustled with trawlers and lobster boats, have been refurbished and converted into upper-middle class condominiums. A majority of the naval yards in Charlestown have also been decommissioned, leaving only the two piers berthing the historic USS Constitution and a small modern frigate.

Ever since the 1700’s, Boston has been the gateway to New England. It was the dominate hub for all traffic moving from Maine to the rest of the country or to Europe, whether the vessels were hauling lumber or transporting passengers on steamship ferries [3]. Despite the changes, Boston is still a maritime-centric city, and is one of the largest ports in the U.S. It has one of only a few operating liquid natural gas port facilities on the East Coast, and is contains large port facilities frequented by cargo carriers and cruise ships. On a micro level, commuter ferry traffic and small water taxis are a constantly traversing the harbor. Even the fishing traditions, albeit smaller, thrive in a town where the fishing industry practically built the city in the early days.

When it comes to maintaining the waterways, the US Army Corps of Engineers frequently survey the inner harbor and dredges the main shipping channels. A great deal of historical information was lost during these dredging operations. The areas surrounding the piers are considered privately owned and maintained, and it is up to the owners to ensure safe navigations.

The water between the piers and the channel is a different situation, as it does not fall with any particular group’s jurisdiction. As a quality assurance measure, NOAA surveyed the entire waters in the inner harbor, right up to the piers, quays and wharfs. All of the groups work with the Boston Pilots Association to assure that dangers to navigation are communicated, charted and rectified.
Facilities along the main waterfront, which have experienced continual expansion into harbor, have buried portions of the old maritime landscape. Contemporary areas holding the most potential for historical information are places between old piers, and spots near the foreshore that have not been developed. This is mostly seen on the East Boston side of the harbor where little waterfront maintenance has taken place over the years. Several wrecks in between the old piers are well imaged. Some are modern, like cars and tugboats, while others include old barges, which were clearly once part of the piers themselves, used offloading platforms or temporary warehouses.

If nothing else, the hydrographic work established a clear baseline for future generations to work from. From a hydrographic perspective, this survey can be compared with future projects to identify changes and where recent dangers to navigation have occurred. From a cultural perspective, researchers have an updated tool they can compare with historical documents and charts to help accurately describe port expansion, and locate where historical building and wrecks may have once been.

4 Exploring the harbor’s islands

Boston’s outer harbor is dotted with historical islands and shoals. The state’s Park Service helps to manage the unincorporated islands, though most fall under the jurisdiction of cities of Boston or Quincy. Some have military significance, housing forts from different eras, and bunkers and lookout areas from various wars [4]. Paddocks Island, for example, was a World War I, training facility complete with barracks, officer housing, a church and explosives range. The islands with structures are in various states of refurbishment, but most are currently left alone, and, aside from Fort Warren on Georges Island, the public visits few.

In 2000, Whiting successfully surveyed the waterways surroundings the islands as they are frequented by small commercial traffic such as commuter ferries, fuel barges and fishing boats. The following year, when the ship returned to survey the Inner Harbor, the crew was enlisted to help an on going project that the University of New Hampshire (UNH) was conducting on Rainford Island. The island has a storied past of inhabitants starting with Native Americans. However, it is most remembered locally as a quarantined area where those suffering from various communicable diseases, such as smallpox, were exiled. The island once housed a doctor’s house, a small hospital, and a series of different piers constructed thought the years. Today, little remains on the island. Structures are gone aside from some concrete foundations.

Just off shore, however, in the intertidal zone and further out, are the remains of some the piers; one of the items a multidisciplinary team from UNH wanted to investigate. The piers themselves have long since deteriorated, but the piling stubs are still evident. The previous year, Whiting had surveyed the area around the island with multibeam and side scan sonar systems. In 2001, working with Dr. Lloyd Huff, a hydrographer and graduate professor at the UNH, the Whiting crew designed a more detailed survey plan (Fig 1).
Maritime Heritage

Figure 1. Side scan sonar mosaic surrounding Rainford Island displayed with the vessel track lines. The sonar system’s range scale was altered for each pass around the island.

Several rings of side scan sonar data was acquired around the island at different range scales and directions. A more complete multibeam survey was run at high tide, so the Whiting’s launches could work close to shore. This was not accomplished during the previous year since that area was too shallow for the Whiting to investigate as part of a navigation survey. The results of the multibeam and side scan sonar surveys revealed several pier foundation stubs in different stages of deterioration. Some of the structures were made of wood, while others of stone.

After the data was acquired, Dr. Huff and a team from the Whiting landed on Rainford Island at low tide to conduct a video mosaic of the foreshore where some of the pier structures were exposed. This experimental imaging technique feeds differential geographic positioning system (DGPS) position data into a video recorder attached to a three-meter high pole. The method of acquiring data is to walk the beach in overlapping transects. The video footage was processed to produces a high-resolution photo mosaic, giving every item a geographic position with sub-meter accuracy. This image correlates with the side scan mosaics and multibeam digital terrain models (DTM).

The mapping tools used around Rainford Island created detailed plots that proved useful to Dr. Huff and his colleagues at UNH. Like every collaborative project, the needs of those intending to use the data must be effectively communicated to those acquiring the data. Without it, the results may be unintentionally rendered useless, and the hydrographers will have wasted their
time. Unfortunately, this has happened on several occasions where hydrographers have worked on benthic habit mapping projects with fisheries groups. By collaborating with UNH archaeologists, Dr. Huff was able to communicate their needs to the Whiting, and provide them with a useful product.

5 Investigating individual wreck sites

Like all bustling ports, Boston Harbor has seen its fair share of maritime casualties, whether tragically haphazard or carefully calculated. During the time of Nathaniel Bowditch, when professional navigation was becoming more of a science than an art, young captains, with little more than a speck of sailing experience, were tasked with piloting their vessels through the rocking channels of Boston Harbor. Few newcomers made it, much to the chagrin of saltier seafarers, and much to the dismay of their finial backers [5]. This is not counting the many ships that foundered during acclimate weather. The Graves, a shoal area near the northern approaches is aptly named due to the ill-fated ships that met their end there. Lifesaving stations, like the one on Hull Island, were established for this very purpose, and saved a great many sailors [4].

Finding these wrecks, hydrographically, is matter of seeing what falls out of the data. After the 200% SSS coverage is acquired, contacts that were deemed bathymetrically significant are further investigated. These contacts are primarily dangers to navigations, isolated features, or man-made objects. NOAA refers to these as “non-skin of the earth” items – anything that protruded from the bottom, and can be classified as a rock, wreck or obstruction. Due to the high amount of glacial till material in and around Boston Harbor, there were about five thousand total significant contacts. Of this group, only about 5% were manmade. Hydrographic surveys, like this one conducted in Boston, frequently uncover wrecks in various states of disarray, but are rarely given any historical consideration once found.

NOAA has a database that archives all these point features gathered from prior surveys and from the U.S. Coast Guard’s Local Notice to Mariners publications. This is called the Automated Wreck and Obstruction Information System (AWOIS), and each hydrographic survey requires the team to prove or disprove every AWOIS item in the survey area. Most of the items in the list are from the 20th century, but some historical items are listed, usually as remains of vessels in various states of decomposition. Any cultural usefulness is derived from entries that are updated throughout the years as surveys are repeated. The approaches to Boston Harbor, for example, are important thoroughfares to a major port, thus NOAA will resurvey the area again within ten years, and the AWOIS items will be reinvestigated. As new items are found or recorded by the Coast Guard or any other source, the AWOIS listing will continue to grow. Without realizing it, hydrographers have been cataloging detail site formation processes for thousands of items for two hundred years. As remote sensing technology advances, the entries become more detailed, and are starting to accompany digital images.
As an example of an AWOIS investigation, similar wrecks were examined near the Brewsters—shoals on the outer, northeastern edge of the harbor. As recent as the late sixties, Boston Marine Disposal would “lose” old barges in this area. Whether by accident or on purpose, these dump scows were reported sunk on a regular basis. Whiting’s survey revealed several of these barges, and found earlier ones that pre-dated the vessels listed in the AWOIS record. Boston has a reputation of having long maritime traditions, which are passed down from one generation to the next as close-knit businesses mimic small families—or vice versa. This is perhaps evident in the informal, though isolated dumping areas frequented throughout the years.

Hydrographic tools not only uncover historical finds, but also offer different perspectives on their condition and site formation processes. The following images are of a barge located in Boston North Channel. The intensity of the return from SSS data (Fig 2) can reveal bottom type and material of the wreck. In this case, the barge is steel because of the hard return and sharp features. The bottom surrounding the barge is sandy, whereas the material is the lower right portion of the image is becoming rockier.

Figure 2. Side scan sonar mosaic generated from Klein 5500 sonar data over an unknown wreck in Boston Harbor’s North Channel. Resolution is 0.5 meters.

The bathymetry data that is displayed through digital terrain models (Fig 3), is more quantitative, and has the ability to provide soundings with remarkable accuracy. When compared to the SSS image, we see the more rocky terrain in the lower right corner is actually a ledge. Pitting is evident on the metal hull, and
a well-defined scour mark encompasses the vessel. In the late 1990's an inbound vessel struck the barge, which prompted an investigation leading to its initial discovery in 2000 by the NOAA Ship Rude. The large indentation amidships is quite possibly from that collision. Arguably this particular site holds no true historical or archeological value, but the type of sub-meter accuracy (both vertically and horizontally) is an efficient method of archaeology site mapping. The days of stringing tape measures underwater may be over.

![Image of barge with inset](image)

Figure 3. Digital terrain model from Reson 8101 shallow water multibeam data over an unknown barge in Boston Harbor's North Channel. Resolution is 0.5 meters with sun illumination of 45° elevation and 45° azimuth.

For ground truthing, the hydrographers selected certain sites deemed dangers to navigation, or items that were just plain interesting. This is a common practice for all NOAA hydrographic operations. At the time of the Boston Harbor surveys, the Whiting had about six qualified NOAA working divers who were formally trained in underwater surveying. Some of the dives consisted of rocks within the channel, but other involved wrecks such as the previously mentioned barge. The suspected collision dent on the wreck was confirmed when paint was observed on item. This data can be further research to see if it correlates with the US Coast Guard incident report written at the time of the accident.

Another item dove on included an old wooden barge located in a naturally deep depression of Boston South Channel. Since all of Boston's waterways are
frequently dredged, historical wreck remains are sometime inadvertently destroyed. Items like this wooden barge, which stay hidden beneath the minimum allowable depths of the channels, have a chance of staying well preserved. As with all items that undergo dive investigations, a sketch of the area was drawn, measurements were taken, and a formal site characterization was written and included with the final Boston Harbor report.

Since the Whiting's mission was strictly to acquire data for hydrographic purposes, wrecksites were not investigated for the sake of maintaining a historical record. Most historical wrecks dating before the turn of the century are not in NOAA’s database, and if they do exist, then they have no substantial relief off the bottom. Only items that are significant dangers to navigation, are particularly abnormal, or are listed in the AWOIS database, warrant investigations.

6 Mapping the whole picture

Many occurrences arise where hydrographers come across historical finds, and take it upon themselves to notify the appropriate management authorities to shed some light on the site. Hydrographers will often put information from outside sources into their reports to provide as many details about the items they investigate as possible.

In situations like this where such high-tech, hydrographic tools are in the area, it would be advantageous for local archaeologists or CRMs to contact the ships. Just because the vessels do not routinely investigate historical sites, does not mean they are opposed to it. If a significant site warrants a investigation for cultural or academia purposes, the hydrographic team should be made aware of it. The expertise is already in the area, and instruments and equipment are ready and calibrated. In most cases, it would take a hydrographic team only a couple of hours to investigate a site and produce professional, accurate results; something that would otherwise take an archaeologist or CRM months to coordinate. The decision of whether or not to undertake such tasks is left to the hydrographic unit’s commanding officer that can best judge his team’s schedule and workload. Should such small sites be addressed, it is often at no cost to the cultural resource team.

The hydrographic tools used to investigate these sites include side scan sonar, shallow water multibeam echo sounders and dive investigations. Although many maritime archaeologists have used remote sensing instruments, few have had enough experience to use the tools efficiently, saving neither time nor money. Hydrographic approaches outlined in this paper include project planning, pre-survey preparations, data acquisition and processing techniques, and post-processing deliverables creation. The main point was not to highlight the history of Boston Harbor, but rather use it as an example of how best to survey an historical harbor given the appropriate tools and proper planning. Hydrographers are the systematic accounts of the ocean bottom, and it would be advantageous of CRMs to take advantage of their highly accurate expertise.
References


