

Modelling Methodologies for Site Management and Preservation Assessment: A Post-WW2 Landing Craft Utility (LCU) Case Study in the Republic of the Marshall Islands

Nathan Richards (East Carolina University)

Jeremy Borrelli (East Carolina University)

ABSTRACT

Ships built in the modern era often have corresponding construction plans, available in various archival repositories. Using such plans, pre-survey site modeling in the CAD-based Rhinoceros software program offers researchers an opportunity to gain detailed knowledge of a vessel-of-interest before an archaeological site investigation commences. This may be particularly important where shipwreck site reconnaissance opportunities are limited or non-existent. The ECU Program in Maritime Studies 2019 Fall Field School aimed to record and assess the remains of a post-WW2 Landing Craft Utility (LCU-1466 class) wrecked in Kwajalein Atoll, Republic of the Marshall Islands. Using a 3D model developed from the builder's plans for the vessel as a baseline to visualize the shipwreck, field school participants gathered supplemental data to track deterioration or modifications on the shipwreck in the form of photogrammetric field assessment (e.g., in Agisoft Metashape) and hand-drawn measurements uploaded to Adobe Illustrator. This presentation will discuss the various recording and modeling methodologies employed during the field school in relation to understanding manufacturing processes, quantifying design deviations during construction, determining if field-expedient modifications exist, charting use-life alterations, gauging the impacts of post-wrecking site formation processes, along with creating 3D and/or 2D visualizations to enhance continued site assessment and community outreach efforts.

Key words: Landing craft, post-WW2, site recording.

List of Figures

Figure 1: Map of "Ski Area LCM" (LCU-1466 craft), Emon Beach, Kwajalein Island, Republic of the Marshall Islands (Image by the authors).

Figure 2: Comparison of LCU-1466 series (top) and LCM-8 series landing craft (Images: Navsource).

Figure 3: Select images of archival/plans used to build LCU-1466 model (depicted images are from BuShips 1967: 4,6, illustrating the outboard profile and main deck plan, respectively).

Figure 4: Result of the pre-fieldwork modeling phase. The resultant model, derived completely from historical records represents an "archetype" of the LCU series namesake, LCU-1466, as defined by the US Bureau of Ships (Image by Nathan Richards)

Figure 5: Depiction of the organization and perspectives of the 28 proformas that would be used would be used to record the Kwajalein LCU. Red arrows denote the orientation of drafting (Image by Nathan Richards).

Figure 6: Isometric results of photogrammetric survey on Kwajalein LCU (Image: Richards)

INTRODUCTION

During the spring of 2019, Dr. Jason Raupp of East Carolina University (ECU) carried out a reconnaissance of a crashed aircraft in Kwajalein Lagoon (site 19-1MH) as a part of a proposed Defense POW/MIA Accounting Agency (DPAA) project, and in the process also carried out reconnaissance of potential field school sites upon the recommendation of local divers. The intention

of the work was to merge a DPAA project and ECU's regular fall field school for 2019. On 16 April 2019 he corresponded with the authors about the potential to work on a "big LCM that broke moorings and sank in a squall in the late 70s or early 80s," within 15-18 feet of clear water off Emon Beach (Jason Raupp elec. comm. 16 April 2019). Critically, the site was close to shore and could be accessed easily without a boat (at coordinates 8°44'5.3"N, 167°44'8.5"E; WGS1984 datum).

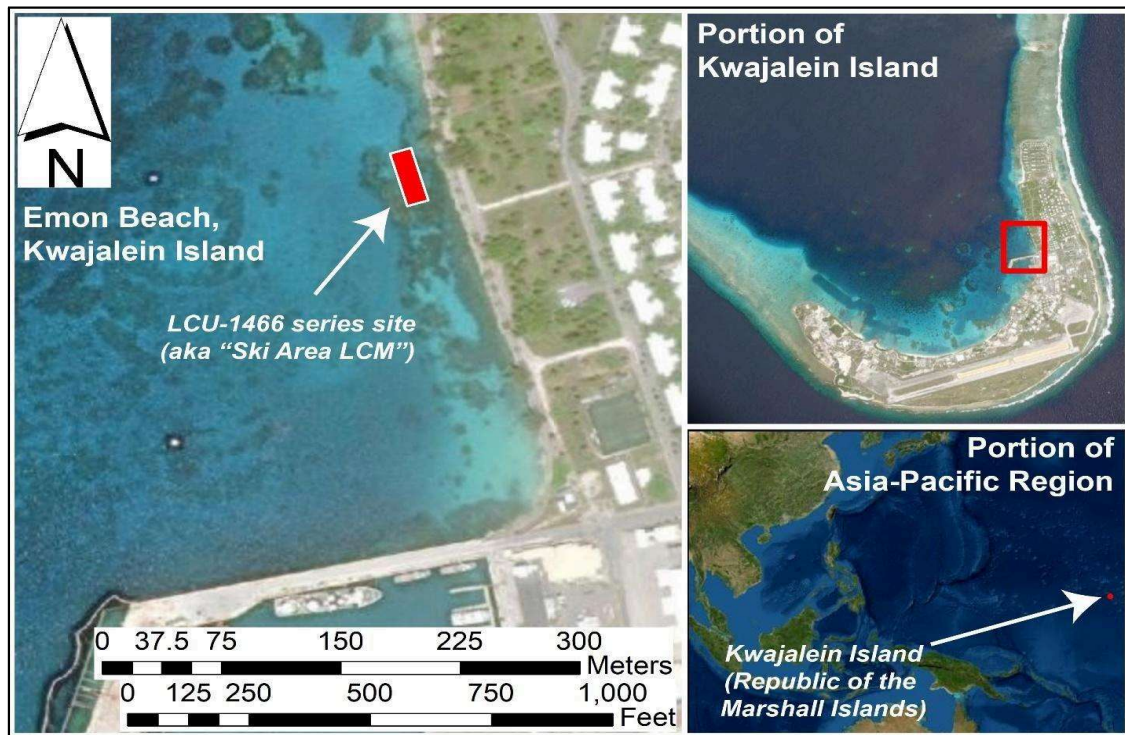


Figure 1: Map of "Ski Area LCM" (LCU-1466 craft), Emon Beach, Kwajalein Island, Republic of the Marshall Islands (Image by the authors).

The identification of the site as a Landing Craft, Mechanized (LCM) was based on local information (see for example, Fortin 2020). Review of video data gave approximate dimensions and provided clues as to the major specifications and design features of the site. It soon became clear that the identification of the vessel as an LCM type, of any US configuration (i.e. Mark 2, 3 or 6 configuration; See Friedman 2002: 212, 290-295; Ireland 2011:184-185, 200-201, 2014:23,25,39,41-42, 52, 54, 87) was incorrect, and the shipwreck more likely a "Landing Craft, Utility" (LCU) type of US design and manufacture, specifically the LCU-1466 series (see Friedman 2002:384-387; Ireland 2011:198-199, 2014:32). In a simplistic way, both designs can be seen to have antecedents in the WW2-era "Landing Craft Vehicle Personnel" (LCVP, also known as "Higgins Boats") types of amphibious landing craft, though in the case of the LCU, an intermediary Second World War type, the US-version of the "Landing Craft, Tank" (LCT) was its direct "ancestor."

Both LCMs and LCUs have very similar appearance, with a box-like hull, built up gunwales, and prominent low-profile pilot houses centrally placed adjacent to a raised poop deck. However, there are major differences. Dimensions across LCM designs differ radically from the LCU-1466 dimensions of 115'-1" x 34' x 6', with the largest of the LCM variants (the Mark 8) having the dimensions of 73'-7-3/4" x 21'-1/8" x 5'-2". While fulfilling similar roles (i.e., the movement of

vehicles and cargo) both vessel types had different handling capabilities due to the LCM's shallow double bottom versus the LCU's deeper double bottom. One of the major differences is in the gunwale design, with LCM types having a built up "dry" double-walled gunwale of greater thickness culminating in a considerable freeboard, whereas LCU types invariably have a low free board with a lightly plated open gunwale that only served as a sort of midship railing (Ireland 2011:201). LCUs and LCMs of these types would be built from the 1950s to the 1990s, though in 1957, LCU craft were radically altered to become a larger type of vessel with a bow and stern ramp (allowing for drive-through capabilities) and a deckhouse offset to the starboard side of the hull (Friedman 2002:385-389; Ireland 2011:198-199). Warren writes of the LCU,

The Landing Craft, Utility-the Navy's largest boat for ship-to-shore movement-can carry 160 tons of cargo through 12-foot seas and deliver it to shore. Its combat radius is 1,000 nautical miles and is capable of independent operations of up to ten days. Yet most sailors outside of the amphibious Navy have never heard of it. At a recent meeting, a Marine officer even asked: "Why do we still use this World War II technology?" Because it works (Warren 1992:72).



Figure 2: Comparison of LCU-1466 series (top) and LCM-8 series landing craft (Images: Navsource).

Various LCU and LCM types (see Table 1) were used by the United States after the Second World War, and some variations are still in military and civilian service. LCU's are seen by commentators as being a successful and flexible wartime and peacetime vessel type:

An LCU can operate independently for ten days or more, limited only by freshwater capacity; reverse osmosis units now being installed will eliminate this limitation.

This endurance makes it a versatile platform. Rather than task a ship to act as a coastal monitoring platform, an LCU with a van on board can be positioned to provide electronic support measures surveillance. With a range of more than 1,000 nautical miles, LCUs provide not only an over-the horizon assault capability, but also independent diversionary assault or amphibious demonstration capabilities. They are excellent platforms for evacuation operations, requiring no reconfiguration, regardless of cargo. The craft immediately transitions from carrying equipment to carrying personnel (Warren 1997:72-73).

Type	Produced	Series numbers	Basic dimensions
LCM, Mark 3	1942-1945	None	50' x 14' x 3'
LCM, Mark 6 (modified Mark 3)	Modification to LCM-3 only, 1943-1945	None	56'-1-1/2" x 14'-0-1/4" x 3'-10"
LCU-1466 series	1952-1957	1466-1609	115'-1" x 34' x 6'
LCM, Mark 8	1959-1992	None	73'-7-3/4" x 21'-1/8" x 5'-2"
LCU-1600 series*	1957-1980s	1610-1681	135'-3" x 29' x 6'

Table 1: Comparison of LCM and LCU types of US design and manufacture (Friedman 2002: 291, 294, 386, 390; Ireland 2011:198-199, 201).

* Sometimes referred to as the “1610 series.” There is some uncertainty about if the 1600-series is broken into multiple types. Some sources discuss the “1610 series” (referring to LCU-1610-1625) in addition to the “1626 series” (1626-1681), or alternatively the “1627 series” (1627-1645) and the “1647 series” (1647-1666) (contrast Ireland 2011:198-199 with Friedman 2002; Navsource 2020a).

Both LCMs and LCUs were in extensive use in the Marshall Islands, and multiple wrecks of each type exist in the country. With the new knowledge pertaining to a potential LCU identification and with historical research scant, the authors sought more information from the public. There was a diversity of opinions

- The vessel is an LCM that sank during the January storm Alice (1979).
- The vessel is an LCM 1500 class that broke from a nearby pier during tropical storm Zelda in 1991. The vessel has three engines inside. A potential candidate is *Neptune*, which had a hyperbaric chamber on board for diving operations
- The vessel is an LCM that broke loose from a dock or mooring in November 1991 (typhoon Zelda) or January 1992 (typhoon Axel) and went onto the rocks, sinking nearby
- During tropical storm Alice (1979), one of the DeLong barges broke her [sic] moorings and crashed into the rocks right in front of trailer T562. By dawn, the waves had used her as a battering ram to knock out a huge section of the rocks before sinking her (Overman 2020).

While the identity of the shipwreck is still presently unknown, these pieces of information were important clues in structuring a search of historical records for the vessel.

There is no LCM 1500 class, but there is the LCU-1466 class (running through the numbers LCU1466-1609, i.e. including 1500 numbers). Of these events, the loss of an LCU during the January 1979 typhoon (Alice) is the best documented and seems to circumstantially point to the identity of the vessel. A 12 January 1979 edition of *Kwajalein Hourglass* includes an article titled “Victims of the Storm” with photographs by Nate Jackson. One of the images includes the caption

The LCU 24 was moored in the lagoon, but as the storm intensified a 1 1/4-inch mooring cable, plus a 5/8-inch chain, plus a 5-inch nylon line parted. The vessel was washed up on the rock shore about 300 yards north of Echo Pier.

As the vessel was pounded on the rocks, it gradually took on water and went down by the stern in 10-12 feet of water (Kwajalein Hourglass 1979:14)

There is no “LCU 24” on record, but there is an LCU-1524 (part of the 1466-series). Navsource (2020b) lists the vessel as named *Chapultepec*, which was laid down at Avondale Shipyard (New Orleans, Louisiana) in 1954 and placed into service the same year. Its final disposition is listed as “wrecked in 1979.” The document, *Registry of Army Vessel Names* also confirms a US Army 1466-series LCU by the name *Chapultepec* but notes a retirement date of June 1991 (Office of the Chief of Transportation [OCT] 2011 2011:18). Tim Colton’s *Shipbuilding* website lists also confirms LCU-1524 was named *Chapeltepec* and adds that it was built and used by the U.S. Army (not the Navy), eventually being “Wrecked, 1979” (Colton 2015). That website lists several other LCU craft connected to Kwajalein Atoll and the Republic of the Marshall Islands, including *Neptune*. Colton notes that there were 142 1466-series LCUs (Table 2).

LCU number	Where built	Hull#	Original owner	Name	F Y	Built	Disposition
1509	Avondale SY	661	U.S. Army	<i>Antietam</i>	52	1954	“To Marshall Islands 1996, wrecked 1998”
1511	Avondale SY	663	U.S. Army	<i>Cumberland</i>	52	1954	“Sold 1994 as <i>Neptune</i> , sank 1999”
1514	Avondale SY	666	U.S. Army	<i>Delaware</i>	52	1954	“Sold 1986 as <i>Tarang</i> , wrecked 1986”
1521	Avondale SY	673	U.S. Army	<i>Eniwetok</i>	52	1954	“To Marshall Islands 1993, scuttled 2002 in Ebeye”
1524	Avondale SY	676	U.S. Army	<i>Chapultepec</i>	52	1954	“Wrecked 1979”
1525	Avondale SY	677	U.S. Army	<i>Hollandia</i>	52	1954	“Served in Marshall I, retired 1990”
1533	Avondale SY	685	U.S. Army	No name	52	1954	<i>Jeremy has photo that could show “33”</i>
1552	Avondale SY	704	U.S. Army	No name	52	1955	“Retired”; Other sources say scuttled as a dock in Majuro after becoming <i>Mesh 3</i>
1593	Kewaunee SC & E	-	U.S. Army	No name	52	1954	“Served in Vietnam, scuttled as dock in Majuro (M.I.)”

Table 2. LCU 1466 series vessels with known connection to Kwajalein Atoll and the Marshall Islands (Colton 2015).

HISTORICAL RESEARCH

With the initial video and photographic data available, and a suspicion that the Kwajalein site was not an LCM, but an LCU, a search commenced to find builders and engineering drawings of the LCU-1466 series. While sources such as Friedman’s *U.S. Amphibious Ships and Craft* (2002) represent encyclopedic accounts of design features and are copiously illustrated, they are not of adequate resolution and detail to facilitate the creation of detailed 3D models. However, a research collection pertaining to the Barbour Boat Works (collection #758) was known to contain extensive

materials pertaining to boat and ship building in North Carolina. The now-defunct company once existed in New Bern, North Carolina where it engaged in recreational boat building and some limited wartime ship construction from 1932 to the mid-1990s (see Barbour Boat Works Inc., 2019). Over these years the company also engaged in repair activities for the US Navy and may have periodically bid on naval contracts. Consequently, a large part of the donation of records to East Carolina University included large amounts of naval builders' plans and engineering schematics from the Second World War to the 1990s, including extensive amounts of material on various types of amphibious landing craft from 1943-1998. Amongst 114 cubic feet of records at least 5 archival boxes pertained to the LCU-1466, including a copy of the original 8-leaf "Booklet of General Plans" published by the United States Navy's Bureau of Ships (known as BuShips) for the original design specifications of the class of vessel (Bureau of Ships). While the booklet of plans is not at an incredibly detailed level of scale (at $\frac{1}{4}" = 1'-0"$), augmented with the various other drawings within the collection, the 5 archival boxes (#758.046-#758.050) turned out to be an incredibly rich record to allow for a complete digital reconstruction of the internal and external features of the literal "archetypical" LCU-1466.

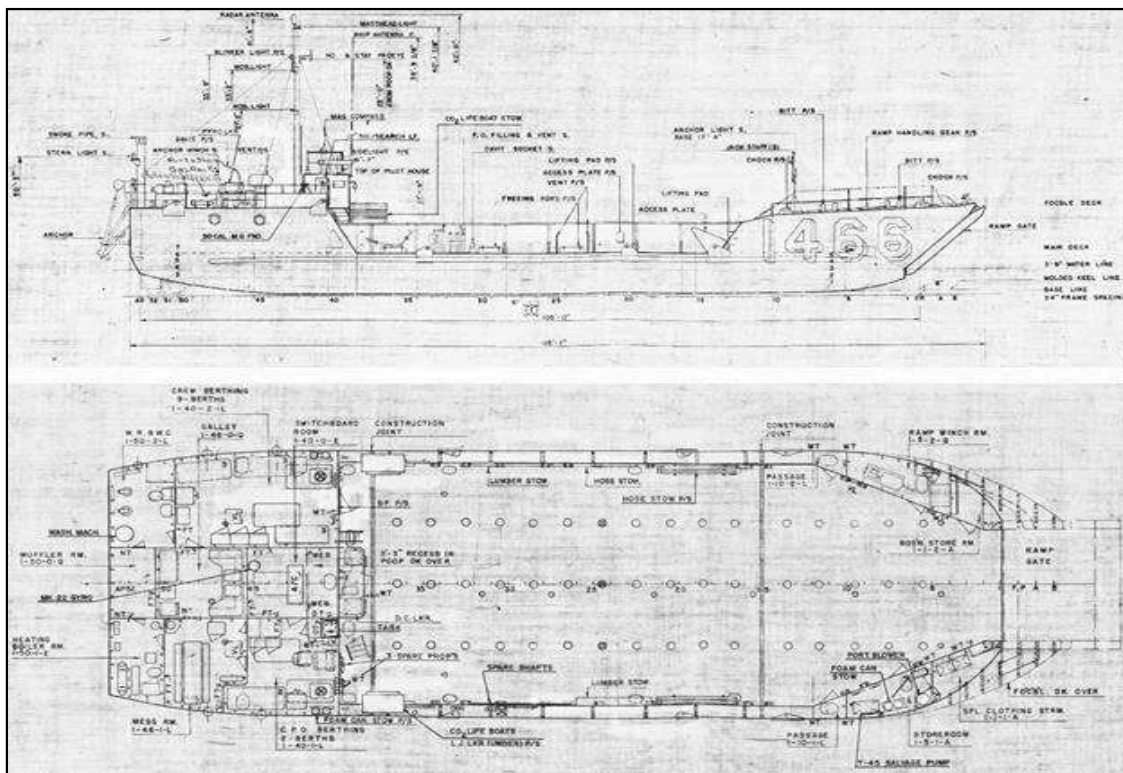


Figure 3: Select images of archival/plans used to build LCU-1466 model (depicted images are from BuShips 1967: 4,6, illustrating the outboard profile and main deck plan, respectively).

PRE-SURVEY SITE MODELING

Six pages of the BuShips booklet was scanned and imported into McNeel *Rhinoceros* (version 6). First the outboard profile drawing was brought into the modeling space and scaled to the units appearing on plan. Subsequent drawings were placed into the correct orientation and snapped into the outlines of the outboard profile and built up ensuring each drawing was correctly registered to

each other and that dimensions were correct in each view. By the conclusion of this process, three categories of drawings (and 9 drawings in all) were initially referenced to one another:

- Plan views (5): main deck, hold, and a sheet depicting the forecastle deck, top of pilot house, and poop deck were divided into three separate views, respectively.
- Profile views (2): inboard, and outboard
- Cross-section views (3): a sheet of midship and type sections was cut into three separate drawings for the creation of three cross-section views (at frames 6, 26, and 41).

The separation of multiple-image sheets was achieved with Adobe *Photoshop* 2020. The booklet did a satisfactory job of showing the design of all aspects of the ship. In a few isolated cases, additional drawings were sought. One deficiency in the available drawings was that no high-quality set of lines was found for the vessel class (likely because the ship type is based on a relatively uniform box shape). However, three cross sections were not enough for quality lofting of the outer hull. Additional cross-section views were sought and found (being three additional views at frames 7, 46 and 50 from a BuShips docking plan (1957) found in #758.050, folder D). Additionally, drawings were sought to provide modeling guidance on the configuration of the aft skegs (Frame 51, found in #758.049, folder A). As all these views were from the initial designs, eventually later drawings of poop deck modifications, ramp construction, anchor cage design, and internal room details would be added after field work). In all 16 drawings (entire plans, or plan fragments divided into separate drawings) were used to create a base model, and a series of design variants. The result is a model with all internal and external structural details and features that could be used to plan and execute a recording methodology and serve as a foundation upon which later site drawings, photographic and videographic data, and photogrammetric models could be compared to and superimposed upon (see Figure 4). The model and the historical records upon which it was built would play a particularly important role in constructing a pre-fieldwork methodology for an isolated site that the authors had not had a chance to carry out reconnaissance on and was suitably simple for use during a field school.

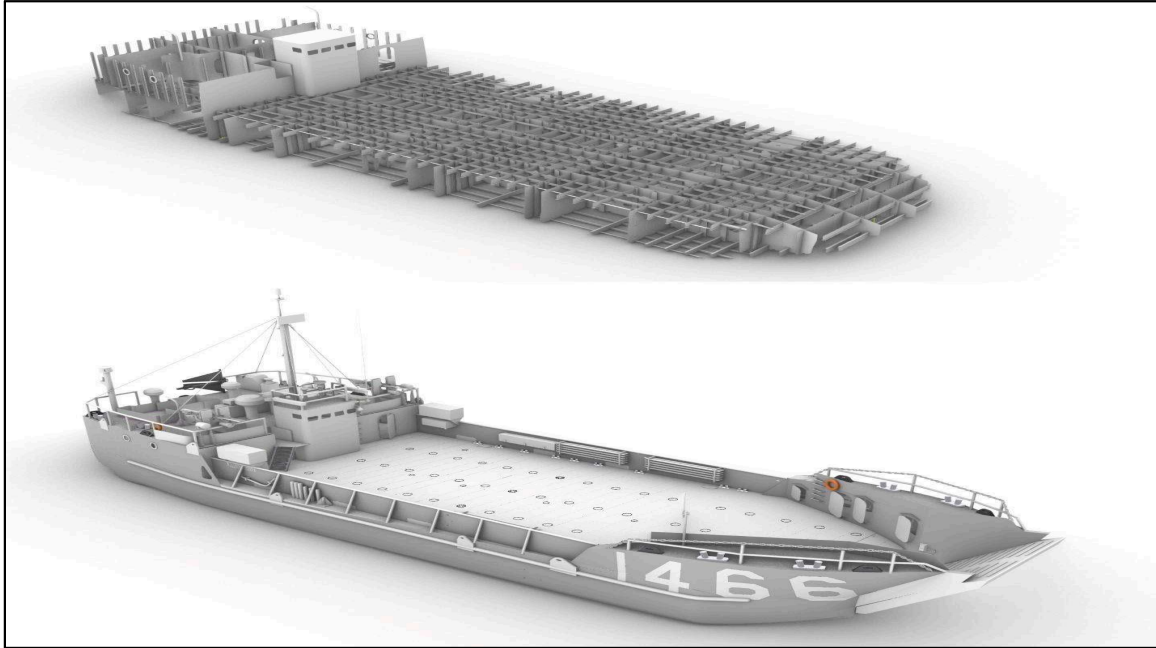


Figure 4: Result of the pre-fieldwork modeling phase. The resultant model, derived completely from historical records represents an “archetype” of the LCU series namesake, LCU-1466, as defined by the US Bureau of Ships (Image by Nathan Richards)

FIELDWORK PREPARATION METHODOLOGY

The 2019 fieldwork was comprised of several knowns and unknowns. Run by Dr. Nathan Richards and Dr. Jason Raupp, the 2019 fall field school had many components, but was held primarily in the Republic of Marshall Islands, with proximity to Kwajalein Atoll (other didactic components would occur in North Carolina after this primary phase of work). Efforts would be directed onto two sites. The first was a DPAA-focused project known as “19-1MH” led by Dr. Jason Raupp and occurring off a limited-berth research vessel. 19-1MH focused on the excavation of an underwater aircraft site upon which students would periodically assist with the screening of marine sediments to identify probative material potentially connected to lost US airmen from the Second World War. The LCM/LCU site would serve as a secondary site. It was selected primarily because it was accessible without boats, in less than 30 feet of water, and a suitable site for training students on traditional site survey techniques, photography, videography, and photogrammetric techniques, and digital drafting when not engaged in screening activities. The goals set by the field school team were to complete a series of scaled drawings (plan, inboard and outboard profiles of port and starboard sites in addition to profiles of the bow, stern, and front face of the forecastle), collect reference material to assist with drafting (photos and video) and complete a photogrammetric model. Information regarding the technical characteristics and site formation observations would also be collected to hopefully confirm its vessel type and perhaps ultimately identify the shipwreck. While the Marshall Islands project period would ostensibly allow for only 7 field workdays (2-9 October), the total number of days available to complete the recording would be unknown because of our need to assist with 19-1MH. Consequently, a streamlined methodology to allow for rapid recording and assessment by an inexperienced student crew was needed. The primary tool for these efforts would be derived from a combination of the original builders plans and the derived *Rhinoceros* model, which would be transformed into a series of predefined forms that field school workers would complete.

PROFORMA DESIGN

With schematics embedded in *Rhinoceros*, and created into a model, orthographic perspectives were extracted and brought into Adobe *Illustrator* for transformation into proformas. All forms were printed on opaque (white) Duracopy-brand waterproof paper. Each drawing had the same size grid of 8 x 13 squares representing an 8 by 13-meter area. Additional room on the form allowed for room to record site name, recorder name dates of recording, perspective, and perspective view number (e.g., plan view drawing #5). In the case of plan and inboard and outboard profile views, drawings representing the extremities of the bow and the stern shared 1 meter of overlap with an adjacent area. The three drawings comprising the middle sequence of each set of 5 included two 1-meter areas at toward the bow and the stern to overlap with the adjacent grids. Each gridded area was also bounded by a color-coded box that would appear on a neighboring form. This allowed for simple orientation of the students to one another while underwater, the duplication of data in bordering areas (for error checking purposes) and sped up the process of referencing drawings to one another during data processing. Ultimately 28 forms were designed: these included plan view (5), port side outer profile (5), starboard side outer profile (5), port side inner profile (5), starboard side outer profile (5), and three cross-sections comprising of bow view (view toward stern), stern view (view toward bow), and poop deck front and pilot house front view (view toward stern) (See Figure 5).

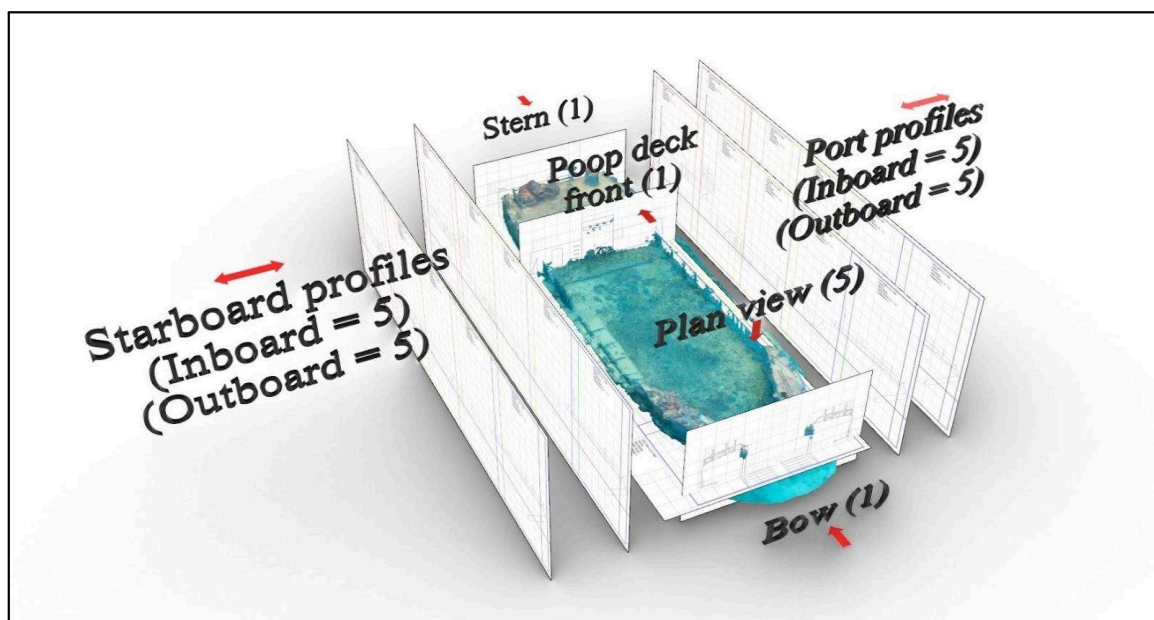


Figure 5: Depiction of the organization and perspectives of the 28 proformas that would be used would be used to record the Kwajalein LCU. Red arrows denote the orientation of drafting (Image by Nathan Richards).

Data collection & Processing

Data collection was comprised of four primary activities. Proforma completion occurred parallel with photographic and photogrammetric data collection. Finally, data was collected to spatially project, and later alter products from modeling (i.e., collection of site tilt data).

Proforma completion

The proformas helped speed up the process by defining the scale for the student, and for setting up the major drafting lines. Where lines conformed to measurements, they were kept as is, where features were gone, they could be crossed out, and where new features were apparent, they could be drafted and annotated simply. This allowed for inexperienced practitioners to focus on proper tape stringing methodologies to collect a small number of high-quality measurements. Individual proformas were scanned and re-embedded in Adobe *Illustrator* (i.e., “snapped” into the original blank templates).

Photographic data collection

As a part of the didactic activities during the field school and to aid in post-fieldwork drafting, the site was documented extensively via videography and photography. A comprehensive video record of all external and internal (pilot house and locations under the poop deck) features and surfaces was obtained with GoPro Hero 5 and Olympus Tough TG-5 cameras.

Photogrammetry

Higher quality photographic recording was undertaken using a standard photogrammetric methodology. Photogrammetric data collection was undertaken by project collaborator John McCord with a Nikon D850 with a Nikkor 16-35mm f/4 ED VR lens set to 16mm. The dome port was an Aquatica 9.25-inch megadome with a lens port extension for the Nikkor lens. The photos were shot in RAW at 8256 by 5405 pixels (47.5 megapixels) and then color corrected and batch processed in Adobe *Lightroom* for eventual exporting as 24-megapixel (6000 by 4000) JPEGs for use in *Metashape* (version 1.6). The flight plan was comprised almost totally of 13 parallel transects swum longitudinally (bow-stern) across the shipwreck, allowing for tilting of the camera to accommodate the “U-shaped” nature of the hull (i.e., to capture the inside surfaces of the forecabin and the internal gunwale). Additional transects were swum completely around the vessel (to capture the raised bow and stern portions) and as two spiral patterns around features on the poop deck, designed to capture the major protruding features of the pilot house and deck winch. All photogrammetric data was captured over the course of one dive.

1671 photos were acquired and 100% aligned, the sparse cloud constituting 1,828,060 points. 13 markers were manually referenced in the model across the length, breadth, and depth of the shipwreck, chosen based upon easily located intersection of steel plates and selected based upon correspondence with the BuShips plans. Four of those markers, representing locations at the extreme ends of the bow and stern were manually georeferenced with the addition of UTM coordinates obtained from a WAAS-enabled GPS unit. From the 13 markers, 5 scales bars were created, and measurements manually inputted taken from measurements from the scaled BuShips plans. Following this camera optimization was run, and a total RMS image error of 0.338 pixels was noted, corresponding to a on overall RMS XYZ error of 0.098m.

A dense cloud was created (medium quality, aggressive filtering) culminating in 180,106,574 points, and from this a mesh of 34,515,653 was produced. The resulting model was too large for practical use and was eventually decimated to 2,000,000 faces for further use in Rhino. Additionally, digital elevation models and orthophotos were exported from the decimated model. A range of orthophotos corresponding with the perspectives of the drafted results (i.e., drawn plans and profiles) were also exported to assist with and provide a check between photogrammetric and hand-drawn measurements.

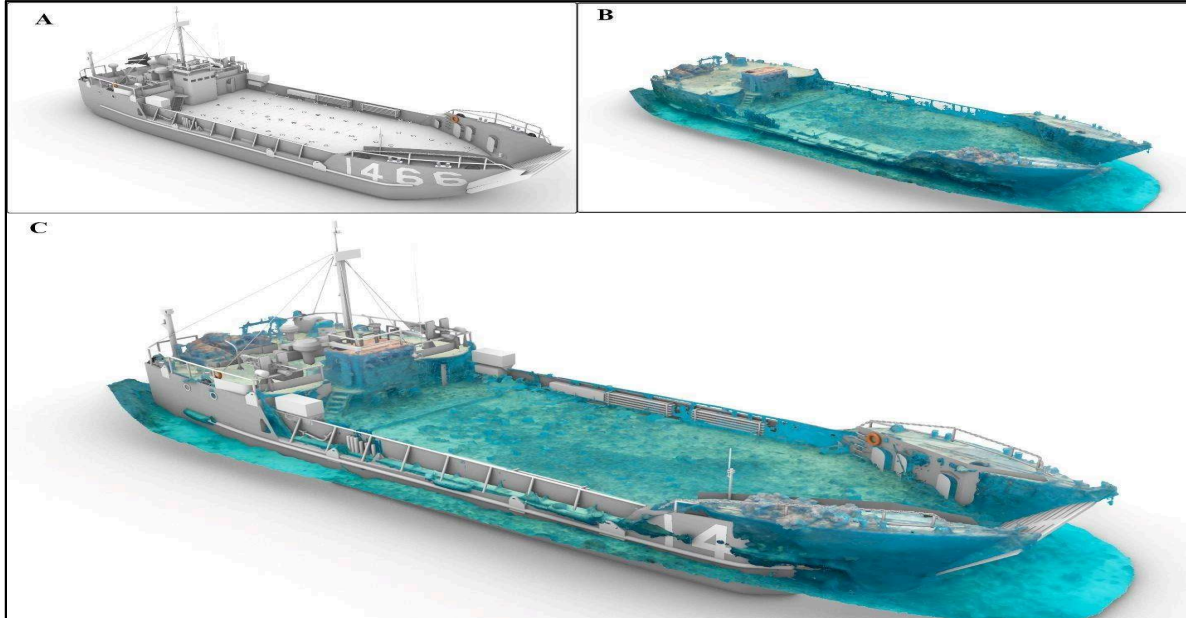


Figure 6: Isometric results of photogrammetric survey on Kwajalein LCU (Image: Richards)

OTHER DATA COLLECTION

One other feature of the recording was that locations on the vessel were recorded with a Pactrade Marine-brand submersible two-scale (i.e., 1° and 5°) boat clinometer. The intention for this measurement was that it would be used to rotate any final model (photogrammetric and Rhino-based) to create true orthographic perspectives and allow for more precision when syncing models to one another. Surprisingly, in this case, angles recorded at “flat surfaces” (poop deck, top of pilot house, and main deck) read between $0\text{--}2^\circ$ to starboard, and $0\text{--}1^\circ$ to the bow. Both measurements are likely within the parameters of instrument error and indicate that the vessel has worked itself into the sand and coral to rest on its flat bottom.

Prospects for Analysis

By the conclusion of fieldwork, the authors had two scaled three-dimensional datasets (a *Rhinoceros* model and photogrammetric model), each augmented by a rich two-dimensional dataset (i.e., photographic and vectorized scaled site drawings). These datasets in themselves serve as a detailed baseline for preservation of the site as of fall 2019 and represent a data that is readily available for public viewing on sites like Sketchfab.com. While outside of the scope of this paper, it is intended to use each 3D model to facilitate a range of analyses to better understand the manufacturing processes of the LCU-1466, quantify design deviations (i.e., by comparing the archaeological and historical models), looking at use-life alterations (repairs, field expedient modifications, and modifications for secondary functions), and quantifying depositional (wrecking) and post-depositional archaeological site formation processes (e.g., deterioration and extent of burial). There is also the potential that future deterioration could be modeled using observations of change up until the time of inspection.

By going through the painstaking process of researching and studying building schematics, and building a three-dimensional rendition of the example, the investigate gains an in-depth knowledge of their subject that perhaps would not be present if builders plans were just collected at reference material. Once historical research began to look at the LCU-1466 class, it became clear that the members of class of vessel was subjected to many forms of modification through their lifespan and were likely modified during the production process. For example, we see significant differences

between the deck configurations represented in the BuShips plan, archaeological site, and historical photographic evidence. This includes but is not limited to the spaces dedicated to anchor winches, armament, storage, and is also noted in the altered use of parts of the watercraft. By the time photographic documentation, and photogrammetric model building these variations in design become obvious.

CONCLUSION

The isolated location of the site, and the limited amount to time allocated to complete the scheduled fieldwork meant that certain short-cuts were made. Among these is the lack of in-water camera calibration, the use of manual referencing markers, and the use of a GPS for position fixing rather than a total station or RTK system. All factors culminate in a photogrammetric product that could have been more accurate. Nevertheless, the process has potential for enhancing future site assessment, and can be used as a community outreach tool.

Acknowledgments

We are particularly thankful for the efforts of our fall 2020 field school “LCU crew” comprised of the authors in addition to Jaqueline Hewett, Mackenzie Mirre, William Nassif, and Patrick Smith. As noted, this project was a research tangent to a DPAA-funded project run by Dr. Jason Raupp (ECU). Although he was consumed with the “19-1MH” during our stay in Kwajalein, Dr. Raupp was critical in all the areas of logistics for the LCU component of the field school and carried out the initial reconnaissance of the site that led to his recommendation to make it a field school site. Another pivotal member of our team included our diving safety officer, Jason Nunn, who also assisted with project photography. Special thanks to John McCord (Coastal Studies Institute) for serving as the photographer, and for running the initial photogrammetric datasets. The authors also wish to thank the Kwajalein MIA Project (Dan Farnham, Tim Roberge, and many others), the Kwajalein dive club, the American Legion (Kwajalein, Post 44), U.S. Army Garrison-Kwajalein Atoll (Jeremy Bartel, Russel Zayas, Jamey L. Norton, and Grant Day), and the staff of the Republic of the Marshall Islands Ministry of Cultural and Internal Affairs, Historic Preservation Office (especially Susan Underbrink).

Bibliography

Barbour Boat Works, Inc., 2019. Finding Aid: Barbour Boat Works, Inc. Records (#758), East Carolina Manuscript Collection, J. Y. Joyner Library, East Carolina University, Greenville, NC. <https://digital.lib.ecu.edu/special/ead/findingaids/0758>

Bureau of Ships, United States Navy (BuShips), 1967. *LCU 1466 Class (for 1466 to 1477 incl, 1481 to 1500 incl only): Booklet of General Plans, Bu Ships No. LCU 1466 – S0103 – 1207731 (restricted)*. Bureau of Ships, United States Navy, Washington, DC. Retrieved from Barbour Boat Works, Inc. Records (#758) Box 47, Folder D, East Carolina Manuscript Collection, J. Y. Joyner Library, East Carolina University, Greenville, NC. Retrieved 12 September 2019.

Colton, Tim, 2015. Landing Craft, Utility – LCU. Shipbuilding History <http://shipbuildinghistory.com/smallships/lcu.htm>. Last accessed online 23 January 2020

Fortin, Dave, 2020. Ski Area LCM. http://www.fortin-home.com/cgi-bin/wreck.cgi?wreck_46. Last Accessed online 23 January 2020.

Friedman, Norman, 2002. *U.S. Amphibious Ships and Craft: An Illustrated Design History*. Naval Institute Press: Annapolis, MD.

Ireland, Bernard, 2011. *The World Encyclopedia of Amphibious Warfare Vessels*. Lorenz Books: Leicestershire, UK.

Ireland, Bernard, 2014. *An Illustrated History of Amphibious Warfare Vessels*. Southwater Books: London, UK.

Kwajalein Hourglass, 1979. Victims of the Storm. *Kwajalein Hourglass*, Friday, 12 January 1979: 4.

Navsource, 2020a. Landing Craft Tank (LCT), Utility Landing Ship (LSU), Landing Craft Utility (LCU) Index. <http://www.navsource.org/archives/10/18/18idx.htm>. Last accessed 22 January 2020

Navsource, 2020b. US Army LCU-1524 Chapultepec. <http://www.navsource.org/archives/10/18/181524.htm>. Last accessed 23 January 2020.

Office of the Chief of Transportation, 2011. *Registry of Army Vessel Names* (10 March 2011). The Office of the Chief of Transportation, Fort Eustis, VA.

Warren, J.L., 1997 “LCUs: The forgotten landing craft,” in United States Naval Institute Proceedings, Vol. 123(11, November 1997): 72-74.

Overman, Tom, 2020. Boating on Kwajalein’s Beautiful Waters. <http://www.shermiewiche.com/kwajmem/story15.html>. Last Accessed online 09 September 2020.