4-2011

The Port Norfolk Project: Improved Raster Navigation Products From High Resolution Source Data

Matt Wilson
NOAA

James J. Miller
NOAA

Vanessa Self Miller
NOAA

Kolleen Mortimer
NOAA

Katrina Wyllie
NOAA

THE PORT OF NORFOLK PROJECT

IMPROVED RASTER NAVIGATIONAL PRODUCTS FROM HIGH-RESOLUTION SOURCE DATA

Matthew J. Wilson, James J. Miller, Vanessa Self Miller, Kolleen Mortimer, and Katrina Wyllie
National Oceanic and Atmospheric Administration
Office of Coast Survey
Atlantic Hydrographic Branch, Norfolk, VA

The guiding principles for the Port of Norfolk Project are to explore viable methods of improvement with respect to both the process and the products of the Office of Coast Survey (OCS). Process improvements might include process efficiencies that decrease the ping-to-chart timeline, minimize errors, or improve clarity or transparency. Product improvements might include providing more NOAA data in our charting products, presenting that data in a more intuitive fashion, or providing it in a format that is inherently more useful. The Port of Norfolk Project Team utilized CARIS Hydrographic Product Database (HPD) in this endeavor because of the software capabilities with regards to a single-source database, the team's collective familiarity with CARIS functionality, and finally, because this was a tool we had access to.

Abstract

With increasing capabilities in technology, modern hydrographic surveys are comprised of similarly increasing amounts of data, only a minute fraction of which is currently available in the nautical charts produced by the NOAA Office of Coast Survey (OCS). Simultaneously, a tremendous amount of effort goes into the generalization and optimal cartographic representation of the hydrographic data onto raster products, from which the vector products are digitized. Preserving and maintaining a single database of high-resolution vector source data will retain—and make accessible—much more of the hydrographic data collected, alleviate the burden of generalization, and would allow for delivery of high-resolution vector products, as well as a very wide selection of raster products.

From high-resolution source data, raster output could be generated at customer specifications. These "user-defined" raster products could be suitably tailored to meet anyone's needs, regardless if they are a mariner, a scientist, a fisherman, a student, or a casual "common man" customer. The "user-defined" concept will ultimately improve our ability to meet the highly variable needs of our customers.

This paper is intended as an exploratory endeavor, specifically, using the Paper Chart Editor component of CARIS HPD to create examples of the kinds of raster products one can create from high-resolution source data, how this process could optimize the current raster chart production workflow within OCS, while also providing a stronger focus on customer service. Finally, the capabilities and lessons learned from the experimentation with HPD will be applied toward the NOAA-wide implementation of Nautical Chart System II (NCSII).

Background

Creating raster navigation products from high-resolution vector source data is a fundamental shift in the traditional production workflow exhibited within OCS. Therein exist the potential for great benefits, while undoubtedly challenges are presented in the implementation of such significant change.

The electronic navigation charts (ENC) currently produced by OCS are constrained by the scale of the raster navigation chart (RNC) from which it is generated. High-resolution vector source data, unconstrained by chart scale, offers obvious benefits, in that the single source data can be used to generate high-resolution or multi-scaled ENC's, and multiple raster outputs, leading to a potential marked improvement in efficiency. A comparison of the current production workflow versus a potential workflow that uses the high-resolution ENC as its foundation is displayed in Figure 1.

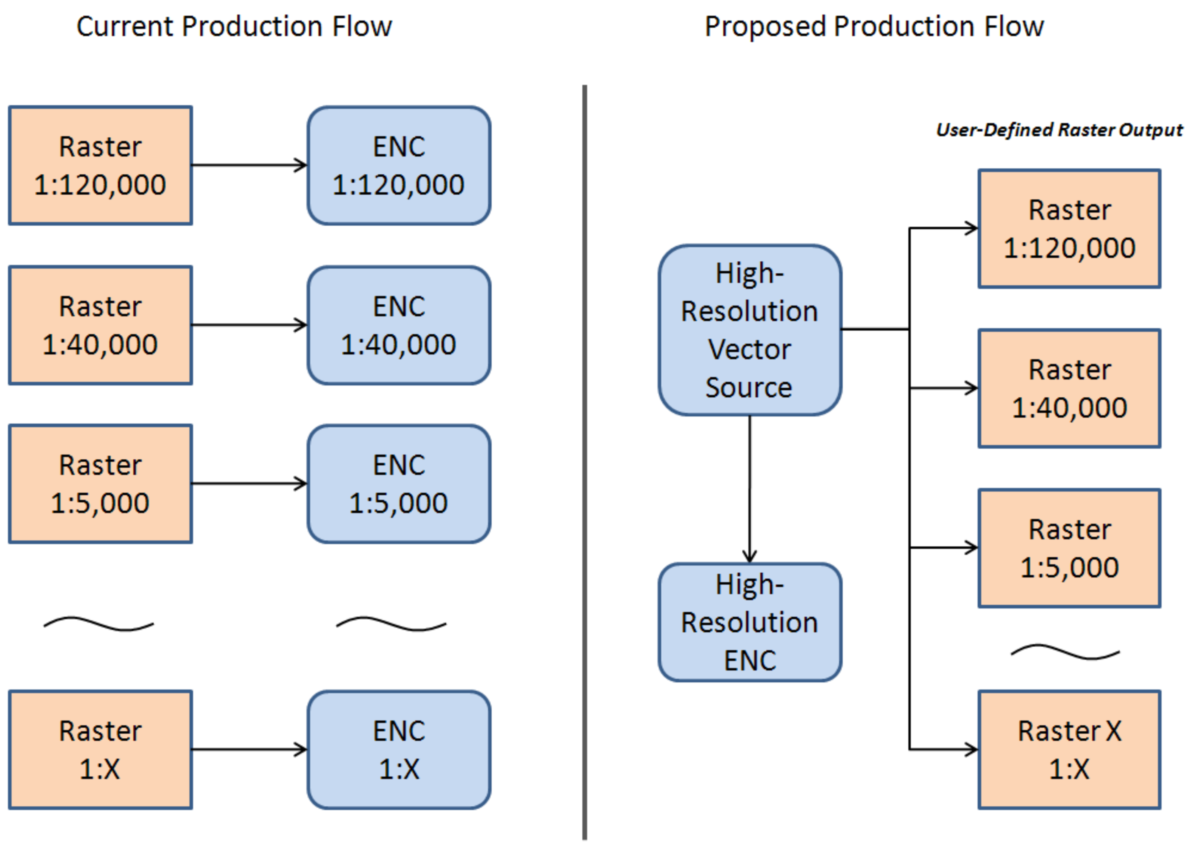

Figure 1: Workflow Comparison

As discussed in other sections of the Port of Norfolk Project, the proposed workflow gains in efficiency is the result of only the vector source data requiring maintenance, as opposed to the current production flow which requires the maintenance and upkeep of a multitude of scale-dependent data sets. Preservation of the high-resolution source data also allows for the delivery of a more robust vector product to the user, as well as the potential for a customized raster product.

The inspiration for user-tailored products comes from a customer service standpoint. To deliver great customer service, it is essential to consider the highly variable needs of our customers, and to cater to those needs. It is a fact that most of the customers of our online charting products are not scientists, or anyone who would know what to do with a Bathymetric-Attributed Grid (BAG) file. As Raymond G. Caputo states: “Organizations that use geospatial data have valuable information locked inside complex applications that only a small number of professionals understand and know how to use effectively. This poses a significant challenge to those attempting to transfer this information to less-skilled end users.” [Caputo, 2010].

The majority of our customers are the “common man”—this is anyone who happens to find their way onto our online charting product downloads via internet searches. The common man is generally not aware of the archived BAG files, nor have they any means for using them. Therefore, the common man will likely find their way towards our nautical chart products online, and if those products do not meet his needs, he or she will go elsewhere. This prospect needs to concern us.

The landscape of mapping and charting is changing rapidly. In these days where everyone has GPS and access to internet resources, if there is a need not being met, people will find a way to meet that need, through open source means, or *Crowdsourcing* [Casey, 2009], which can be defined as an online forum designed to give people the information or solutions they are in need of. We need to stay current, to be aware of these trends, and we need to get onboard. People want what they want and they want it now, and if we can’t deliver the product they desire, they’ll go somewhere else and they will find it.

The Port of Norfolk Project Team is based in Norfolk, Virginia, at the NOAA Atlantic Marine Center, homeport of the *NOAA Ship Thomas Jefferson*. Consider the largest-scale chart in this particular area around the Marine Center and the information it offers, as viewed in Figure 2.

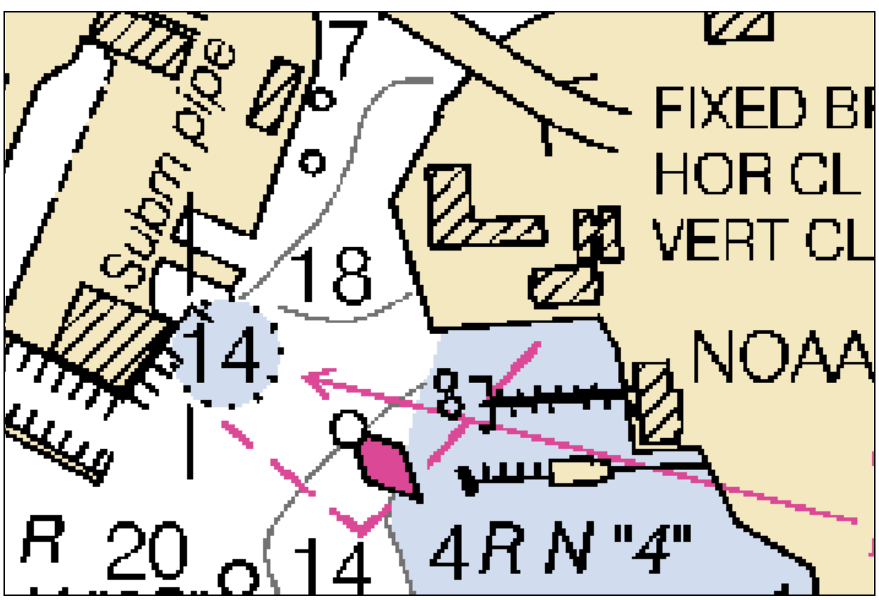

Figure 2: Snapshot of Chart 12253

For whatever the particular usage of the average customer in this location, Chart 12253 would offer 4 or 5 soundings and a couple contour lines in this immediate area for the common man to use for whatever his needs are, when in fact, we have a thousand times more information than this.

The goal of this paper is by no means to promote the use of raster products over the correlating vector dataset. It is instead based on customer service—it is a means to address and facilitate all conceivable requests from all possible users of OCS charting products. A high-resolution vector product is powerful indeed, considering the amount of information it can contain, and also how it can be incorporated into shipboard Electronic Chart Display and Information Systems (ECDIS), from which point users can tailor their chart display, query items for more information, and set safety and alarm depths to aid safe navigation. However, there are some that will always prefer to utilize a raster chart for their particular needs, or, whichever tool may be available to the common man.

The goal of this paper therefore is to consider a raster-based solution for each potential user's need or desire, whatever those may be, and to propose that these solutions be made accessible from an online web interface. The end result of this customer experience would be a downloadable raster chart product in a user-friendly format, be it GeoTIFF, BSB, or perhaps the Georeferenced PDF (GeoPDF), developed by TerraGo Technologies, and which can be utilized by anyone with Adobe Reader and a free plug-in from TerraGo [Caputo, 2010]. With high-resolution source data, and one of these commonly used output formats, we could support any conceivable request. We already have the data—there shouldn't be any reason why we can't deliver it to the customer in a format they can use.

Consideration of Scale-Dependent Data for the Port of Norfolk Project

The Port of Norfolk Project Team, in conjunction with *NOAA Ship Thomas Jefferson*, will acquire multibeam data in the Elizabeth River, as well as side scan sonar for feature verification, and finally, shoreline delineation accomplished by way of both high-resolution orthoimagery and horizontal laser scanning. For the purpose of this paper, high-resolution source data was compiled from multibeam data acquired by the R/V Bay Hydro II in 2007, and this data includes soundings, depth contours, and depth areas at 1:20,000, 1:10,000, and 1:5,000 scales. In addition, depth contours and depth areas at half-meter and decimeter intervals were created and incorporated into the source data, to preserve the known bathymetry to a much greater degree than a standard ENC. All of these components were imported into the Source Editor of CARIS HPD, a seamless database solution which uses Oracle data processing. The imported S-57 components were then reviewed and validated within HPD Source Editor.

At this point, the source data contains sets of bathymetric data constructed at various scales. As addressed in the other sections of the Port of Norfolk Project, there exist significant challenges in the disposition of bathymetry and features in the vector source database with regards to viewing scale. Viable methods to account for this scale-dependent disposition are considered in those papers, and these methods include effective usage of the scale-minimum (SCAMIN) and scale-maximum (SCAMAX) attributes of the vector source data [Miller et al., 2010], or perhaps by a scale-dependent algorithmic generalization yet to be developed [Wyllie et al., 2010]. By either of these means, if the scale-dependent disposition of features is maintained in the source database, then the raster products derived from that database, regardless of scale, can all have the same source—an ideal goal.

For now, the various "Usages" within HPD Source Editor contain the various scale-dependent data sets associated with this project. Within HPD Source Editor, these "Usage" levels can be customized by the user at various scales, and both vector and raster products derived accordingly.

The issue of scale-dependent disposition of features and bathymetry is an ongoing consideration for the Port of Norfolk Project. The absolute best-case scenario envisioned by the Port of Norfolk Project Team would be if the source database could facilitate the finalized bathymetric surface from the hydrographic survey, and all scale-dependent bathymetry and cartographic products were derived directly from this surface. This would retain the resolution and authenticity of the source bathymetry, and the database software could extract the necessary bathymetric components directly from the source surface. Already the extraction of these bathymetric components is mostly automated, and full automation of these components would alleviate the significant amount of time and effort spent manually creating, editing, and maintaining scale-dependent bathymetric components for chart products. Ideally, only this source bathymetric surface would be maintained in the source database, and all products derived thereafter would be suitably updated in an automated fashion.

Raster Production for the Port of Norfolk Project

CARIS Paper Chart Editor was utilized for the raster production from the high-resolution source data. The raster production, with various user-defined specifications, was not difficult; that being said, the resulting raster charts did not entirely produce themselves, and did require manual editing to a degree. Paper Chart Editor converts the S-57 source data to the specified raster presentation display—for this project, the International Hydrographic Organization's (IHO) INT1 format was utilized. However, an output display format tailored to NOAA charts is currently in development, which will allow for presentation of all charted features in the NOAA-standard chart symbols, abbreviations, and terms.

In Paper Chart Editor, much of the conversion from S-57 to INT1 is automated. Figure 3 displays the S-57 source data for the Port of Norfolk Project at a 1:20,000 scale, as observed in HPD Source Editor.

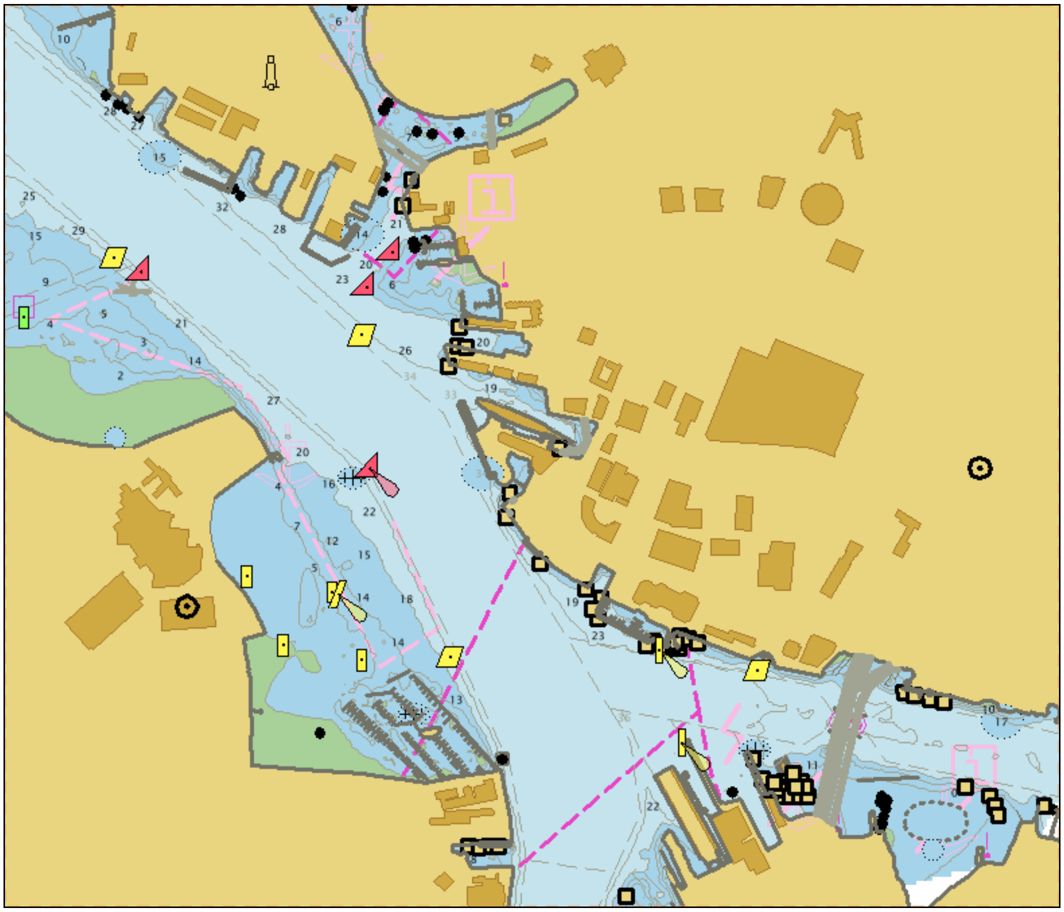

Figure 3: Port of Norfolk Project S-57 Source Data 1:20,000 (units in feet)

Figure 4 shows the above source data after conversion to INT1 in HPD Paper Chart Editor. Figure 4, and all ensuing Figures that display raster output associated with this project, is shown in GeoTIFF format, although each of these products was also output by HPD Paper Chart Editor in BSB raster format as well. In addition, each of the raster products to follow were created with a user-defined size and scope suitable for display in this paper, and were never intended to be printed or used for any other reason.

Figure 4: Port of Norfolk Project 1:20,000 scale data after conversion to INT1 (units in feet)

Note that the soundings, features, aids to navigation, depth areas, contours, fairways, bridges, and land areas associated with this geographical area were converted automatically to INT1 presentation at the appropriate scale. However it was then necessary to manually add the desired chart display items and symbols (title blocks, notes, organizational seals, borders, graticules, scale bars, compass, etc.) as well as various chart annotations (including buoy attributes and feature labels), and finally, contour labels. Masking items, for optimal chart display, can be mostly automated in the Paper Chart Editor user interface. The finalized 1:20,000 scale raster chart produced for this project is displayed in Figure 5, and this contains a level of information, in this specified area, equivalent to that of the existing largest scale raster in this area, Chart 12253. Figure 5 soundings are in feet, and the contour interval standard for a NOAA chart of this scale (0, 6, 12, 18, and 30 feet).

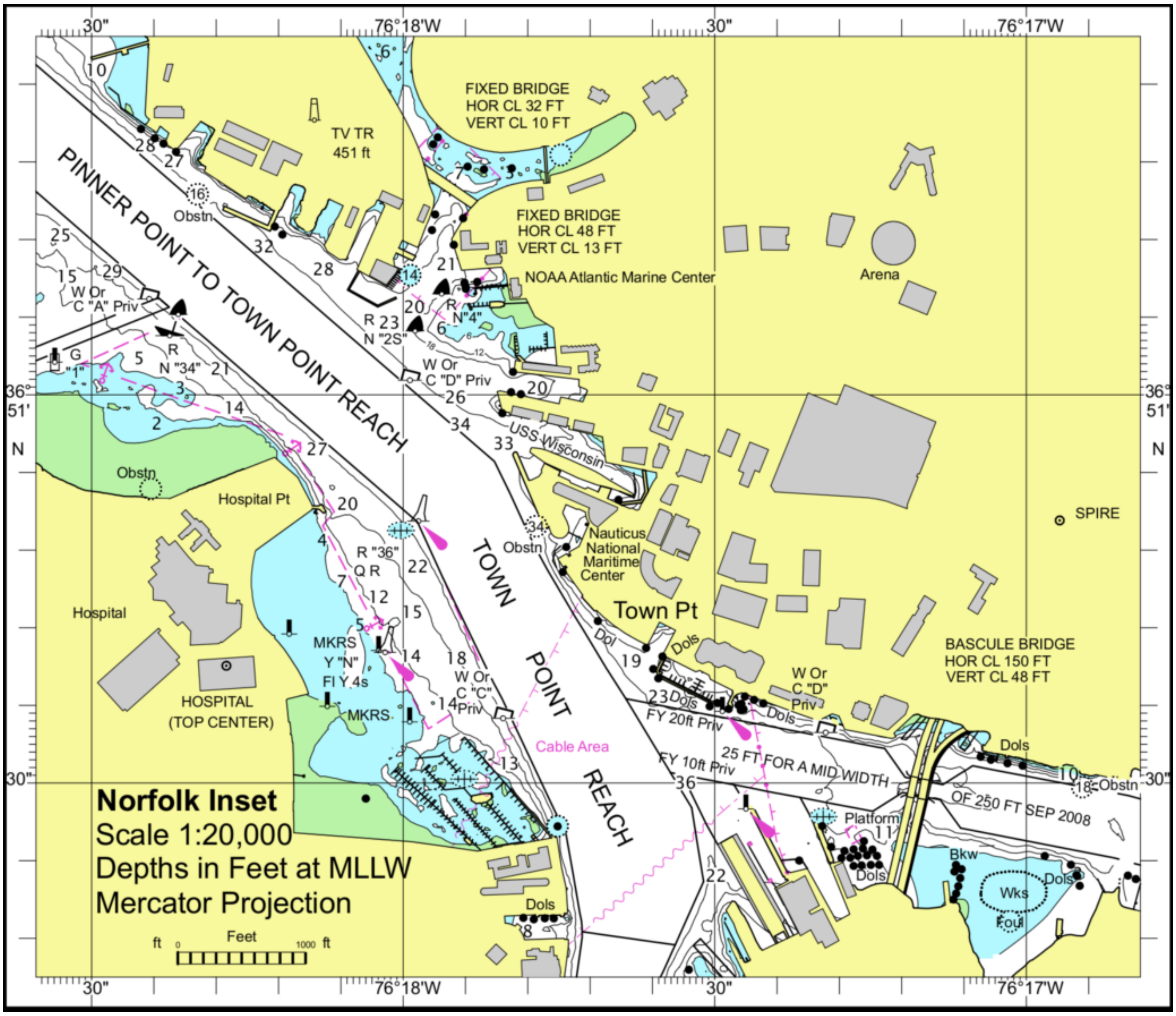

Figure 5: Norfolk Inset 1:20,000 scale (units in feet)

Much of the above-mentioned manual input could be automated in order to expedite this process of raster finalization. Ideally, raster production from high-resolution vector source data would only require the following input from the user: a specified bounds (lat/lon), a chart scale, sounding units (if soundings are desired), and the desired contour intervals.

Necessary chart text for features, landmarks, and aids to navigation are already contained within the S-57 source data, thus this could easily carry over to the raster in an appropriate font size given the user input of scale. Masking around all text, to improve the appearance of the finished raster, already requires very little manual intervention, and could easily be queued in the automated process.

Border items such as ticks, graticules, and labels could be easily generated automatically based on the user input of geographic bounds and scale. However, additional consideration would be necessary regarding the optimal placement of a title block, notes, organizational seals, and scale bars, as it would be near impossible for an algorithm to decide where best to place these items as to not interfere with the desired bathymetry. To mitigate this problem, all chart display items, such as title block information, notes, organizational seals, and scale bars, would be placed outside of the chart window, in what is effectively a chart "bar", generated completely outside of the borders, and not intrusive to the relevant chart window information. An example of a proposed chart "bar", which would greatly facilitate this automated raster generation process, is displayed in Figure 6 (scale bar placed for display purposes only and is not to scale).

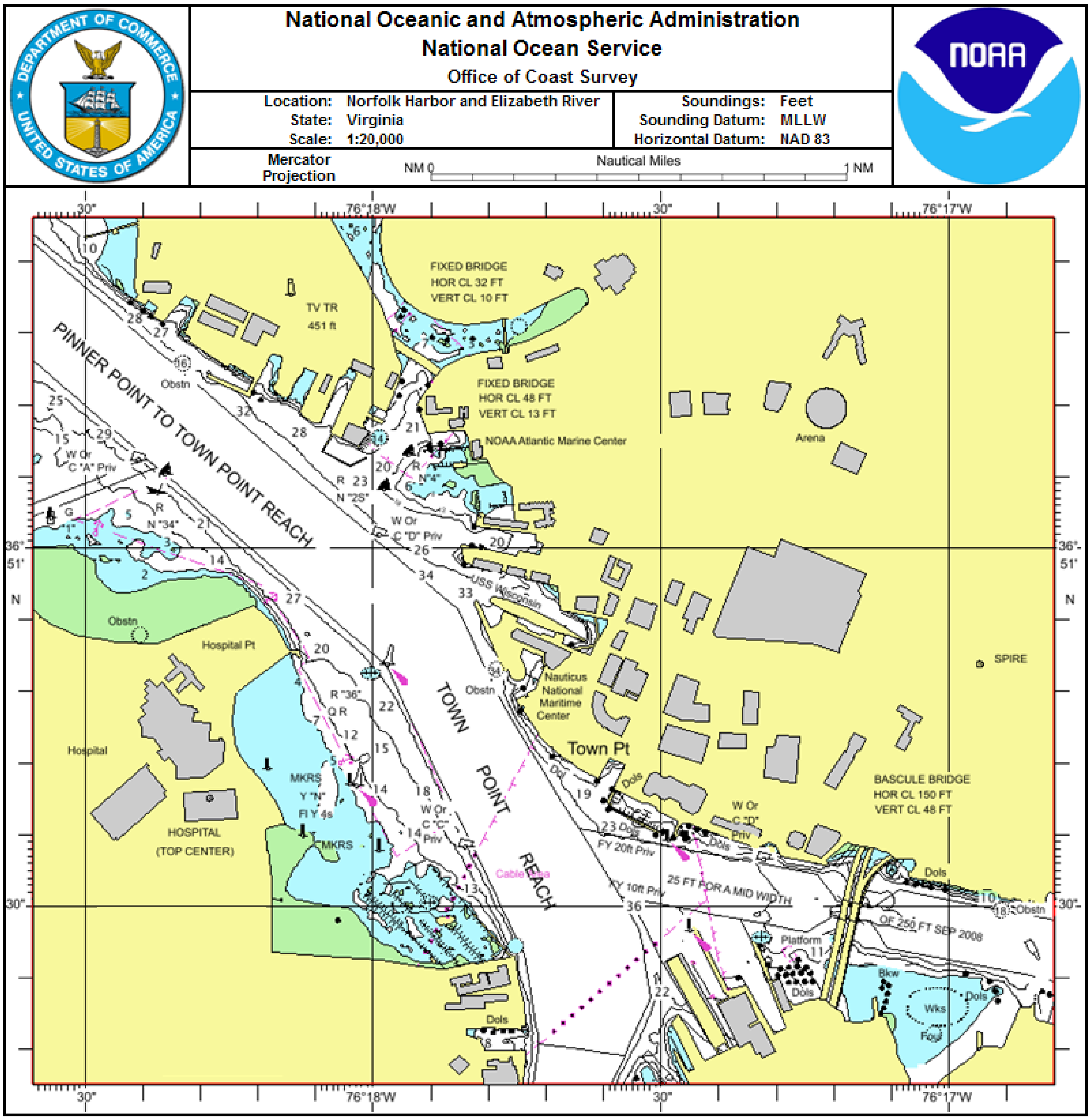

Figure 6: Example of a raster chart product with a proposed "Chart Bar"

Using the high-resolution source data, raster products were also created at 1:10,000 and 1:5,000 scales for the Port of Norfolk Project, as observed in Figure 7 and Figure 8, respectively. Soundings remain in feet and the contour intervals at the NOAA standard (0, 6, 12, 18, 30 feet). Note that the channels of each chart are populated with soundings to reflect the bathymetry in these areas. This could easily be another user input, in the case that the user desired more bathymetric information than what is given in the controlling-depth table of the channels, as per standard raster display format.

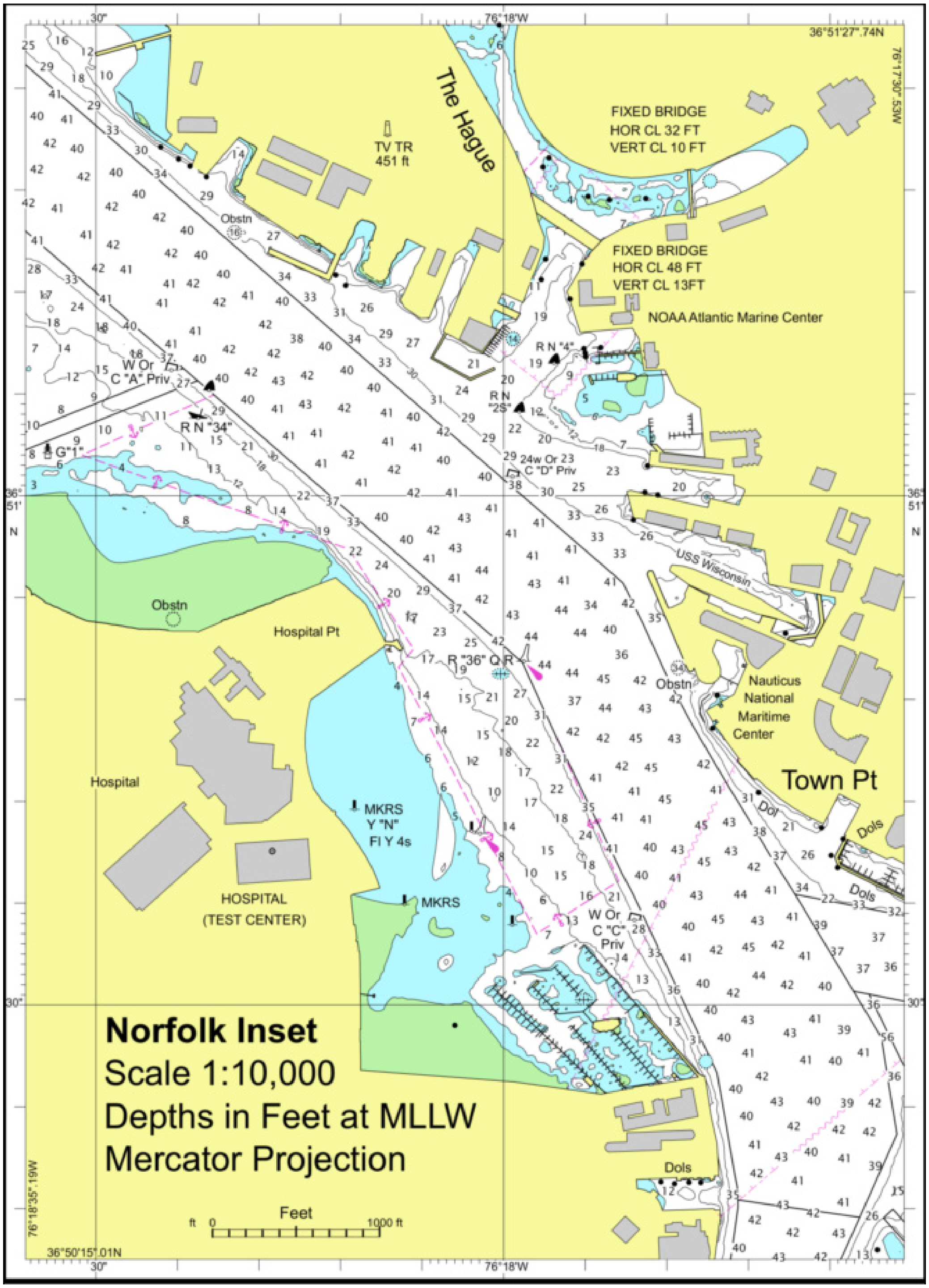

Figure 7: Norfolk Inset 1:10,000 scale (units in feet)

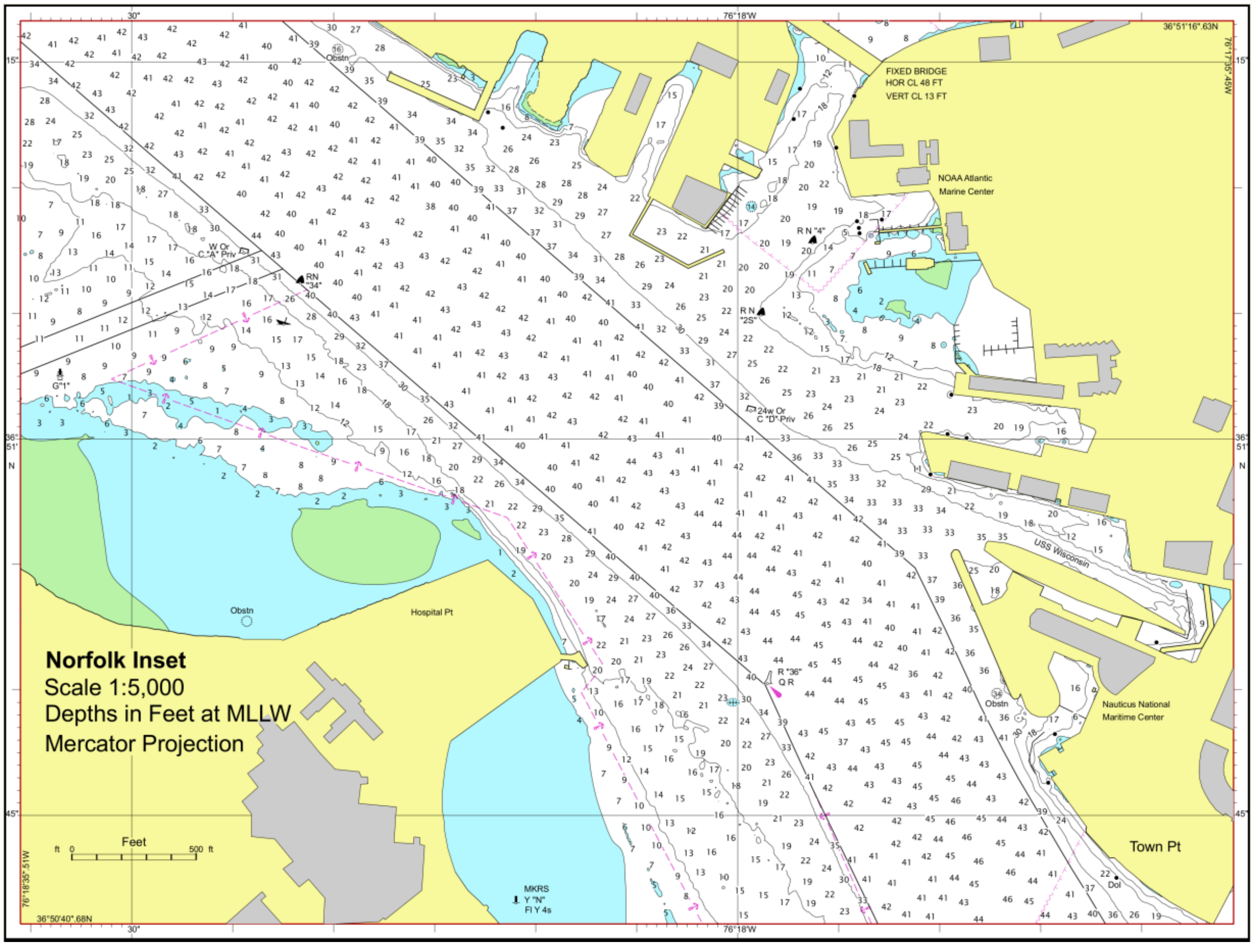

Figure 8: Norfolk Inset 1:5,000 scale (units in feet)

Figure 9 is the 1:5,000 scale raster chart of the same specifications as the chart shown in Figure 8, except it is published in meters, as HPD Paper Chart Editor can facilitate this request.

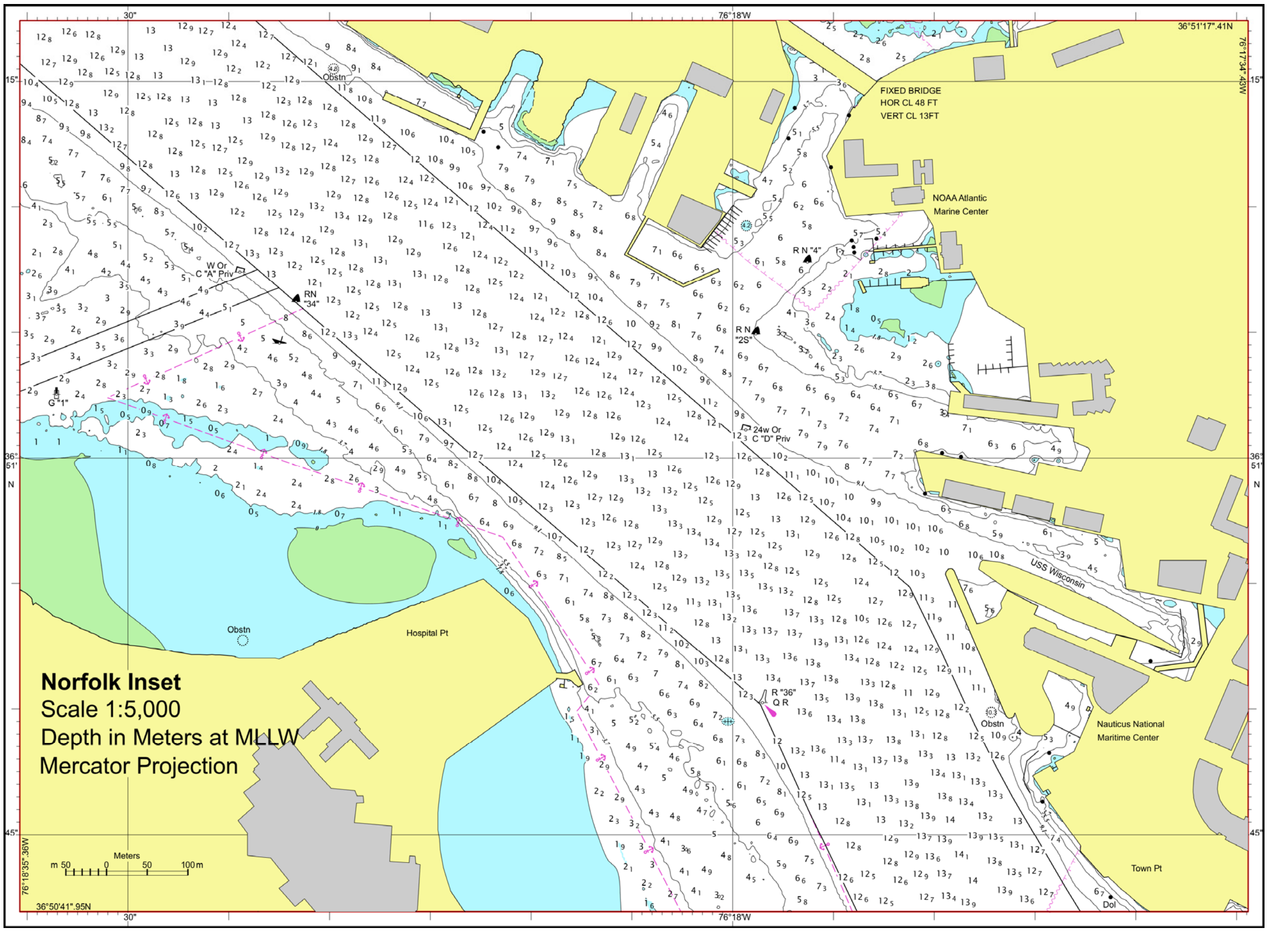

Figure 9: Norfolk Inset 1:5,000 scale (units in meters)

Figure 10 represents a significant departure from traditional OCS raster products, in that the chart, generated at a 1:4,000 scale, has no soundings, and bathymetric representation is accomplished through the use of 50 centimeter-interval contours, with contour labels in meters. This is easily accomplished in HPD Paper Chart Editor.

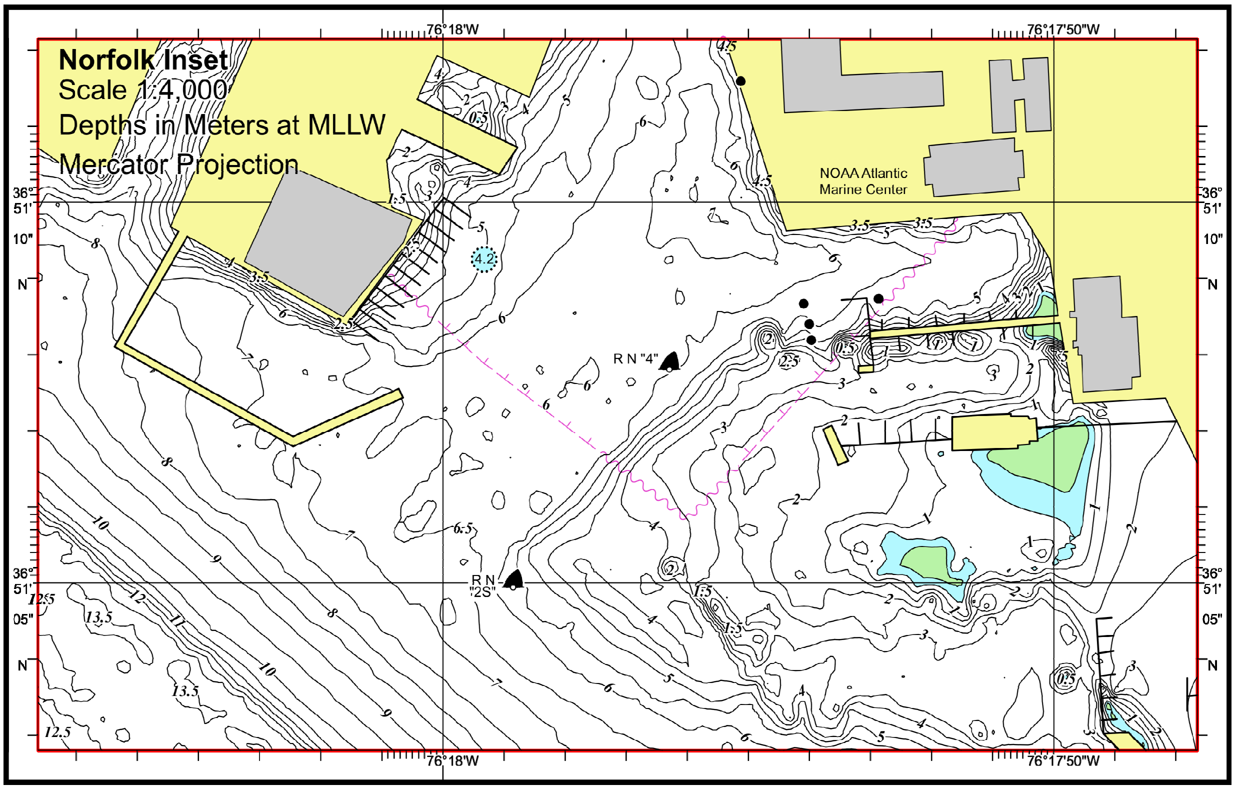

Figure 10: Norfolk Inset 1:4,000 scale, with 50-cm Contour Intervals (units in meters)

Finally, Figure 11 contains the highest level of bathymetric representation, displayed at a 1:2,000 scale, with decimeter level contours, with labels in meters, focused on the NOAA Atlantic Marine Center ship berths.

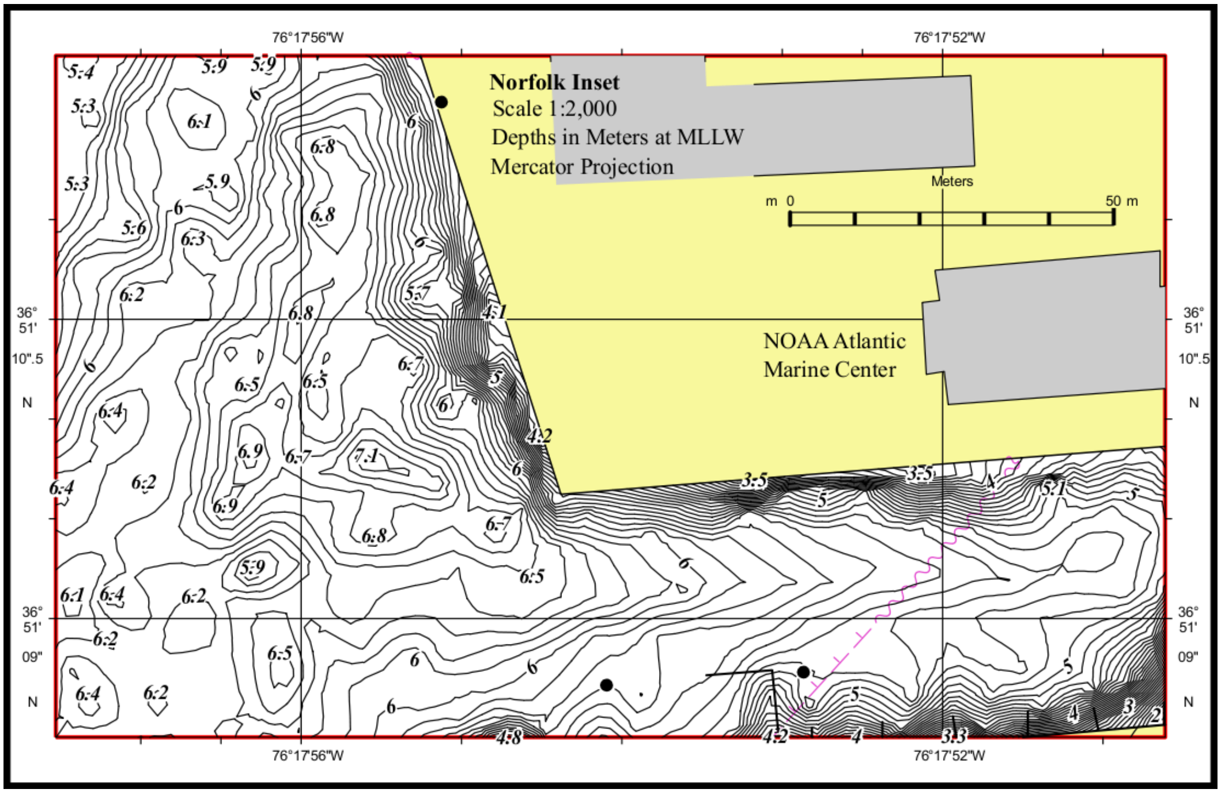

Figure 11: Norfolk Inset 1:2,000 scale, with decimeter Contour Intervals (units in meters)

Figure 11 contains the highest level of bathymetry that we'd like to be available to the public in our charting products, and it contains considerably more information than the current largest-scale chart product available in this location, as viewed in Figure 12 (for comparison purposes).

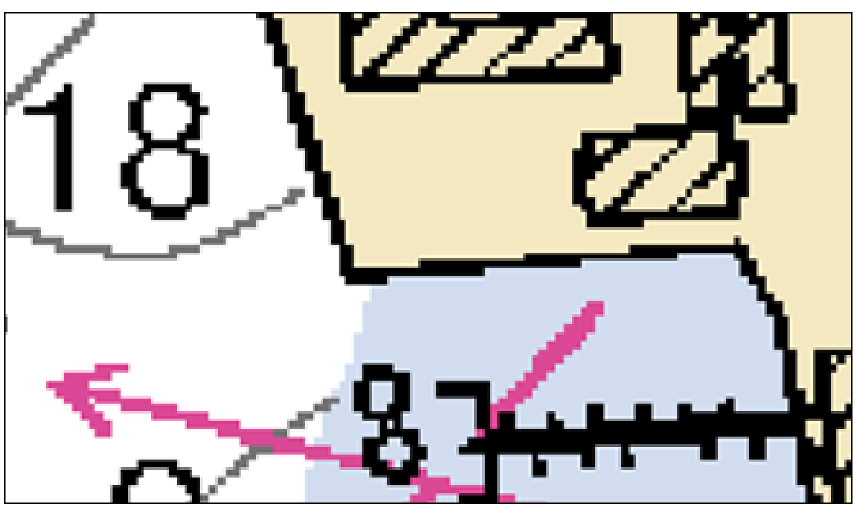

Figure 12: Snapshot of NOAA Atlantic Marine Center on Chart 12253

The raster display of the high-resolution depth contours observed in Figures 10 and 11 required an additional level of manual intervention from the previous rasters (Figures 5-9) to appropriately label the contours. However this too could be automated—contour label size is a function of scale (user input), as is contour label spacing along contours of significant length. The question becomes, which contours are to be labeled? In the examples provided in Figures 10 and 11, all deep and shoal contours were labeled, and additional contour labels were given to contours at each whole-meter value (i.e., 0.0, 1.0, 2.0, 3.0, etc), an algorithm suitable for automation, given checks made to ensure user requests of contour complexity versus geographical area and scale are realistic and therefore feasible.

An ideal scenario for raster chart products such as those observed in Figures 10 and 11 would be if the depth areas could be color-coded according to that particular depth attribute, which would alleviate the need for so many contour labels, as well as make the product instantly more intuitive, creating what would almost be a de facto bathymetric surface within the chart product itself.

It is possible within the CARIS framework to apply color intervals to contour files. When a decimeter-interval color file is applied to decimeter-interval contours, the results are notable, as displayed in Figure 13, but the presentation is too busy and distracting, and not as effective as color-coded depth areas would be. In either case, the currently available presentation formats in Paper Chart Editor would not support color-coded depth areas or contours in the creation of a raster product.

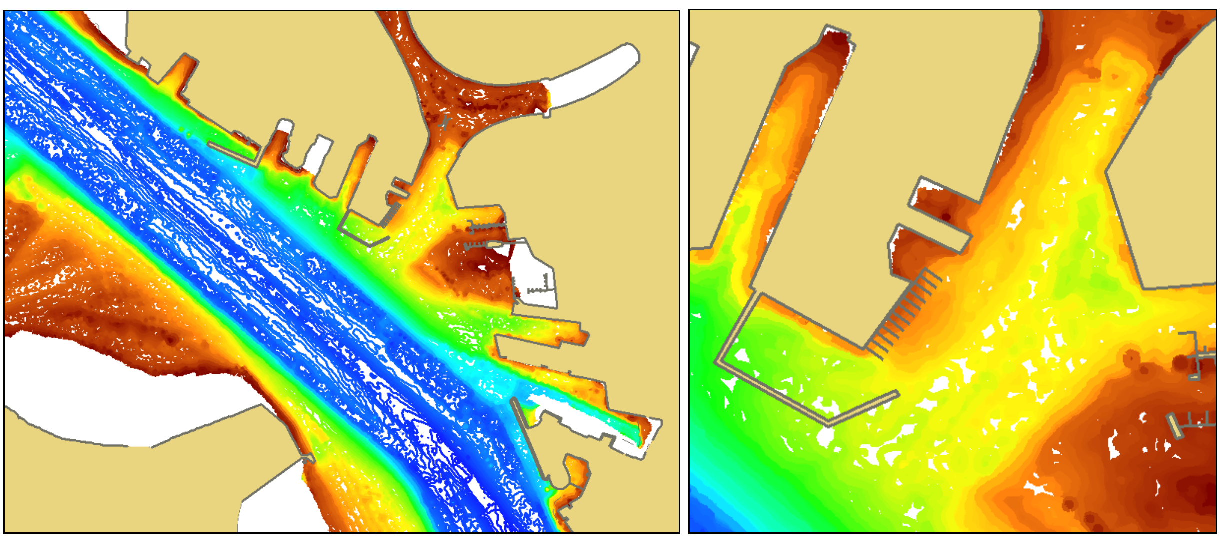

Figure 13: Color-coded decimeter-level contours

As a final note, it is likely that a user-defined raster product, created in an automated fashion, could not be deemed suitable for navigation. The information contained within these products would instead be marketed to represent the bathymetry as accurately as possible, using the best technology and practices, at that snapshot in time, and to be used as a supplement to the existing tools at hand.

Raster Generation with a Bathymetric Surface

As mentioned previously, the inclusion of a bathymetric surface in the source data presents the best-case scenario for nautical chart generation, in that the highest resolution and authenticity of the bathymetry remains intact, efficiency is gained due to less time spent manually generalizing bathymetric components at various scales, and, finally, the raster products derived in part from the bathymetric surface are improved tremendously.

Currently, Paper Chart Editor does not support the inclusion of a bathymetric surface in the creation of a finished raster. It does however have the capability to support GeoTIFF images, or, in this case, a GeoTIFF image of a particular bathymetric surface. The resulting raster product is then restricted to GeoTIFF or PDF format, as BSB export does not support the high-resolution imagery of a bathymetric surface.

The following Norfolk Inset examples incorporate the bathymetric surface as a GeoTIFF, presented here purely for demonstration purposes.

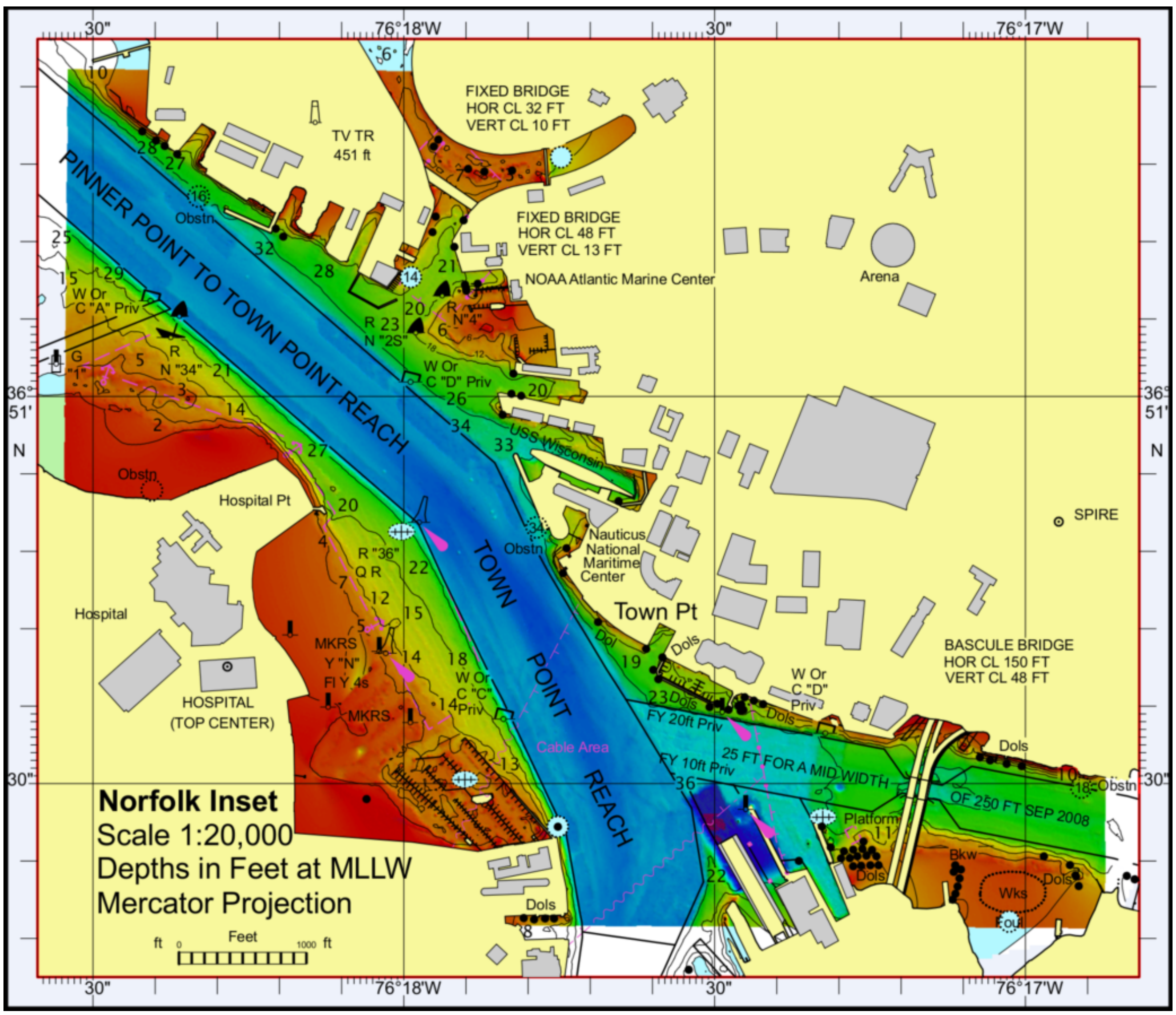

Figure 14: Norfolk Inset 1:20,000 (units in feet), displayed with bathymetric surface

A closer look at the Norfolk Inset at a 1:5,000 scale is displayed in Figure 15. This is a demonstration of bathymetry observed within the channel, as viewed in a raster product.

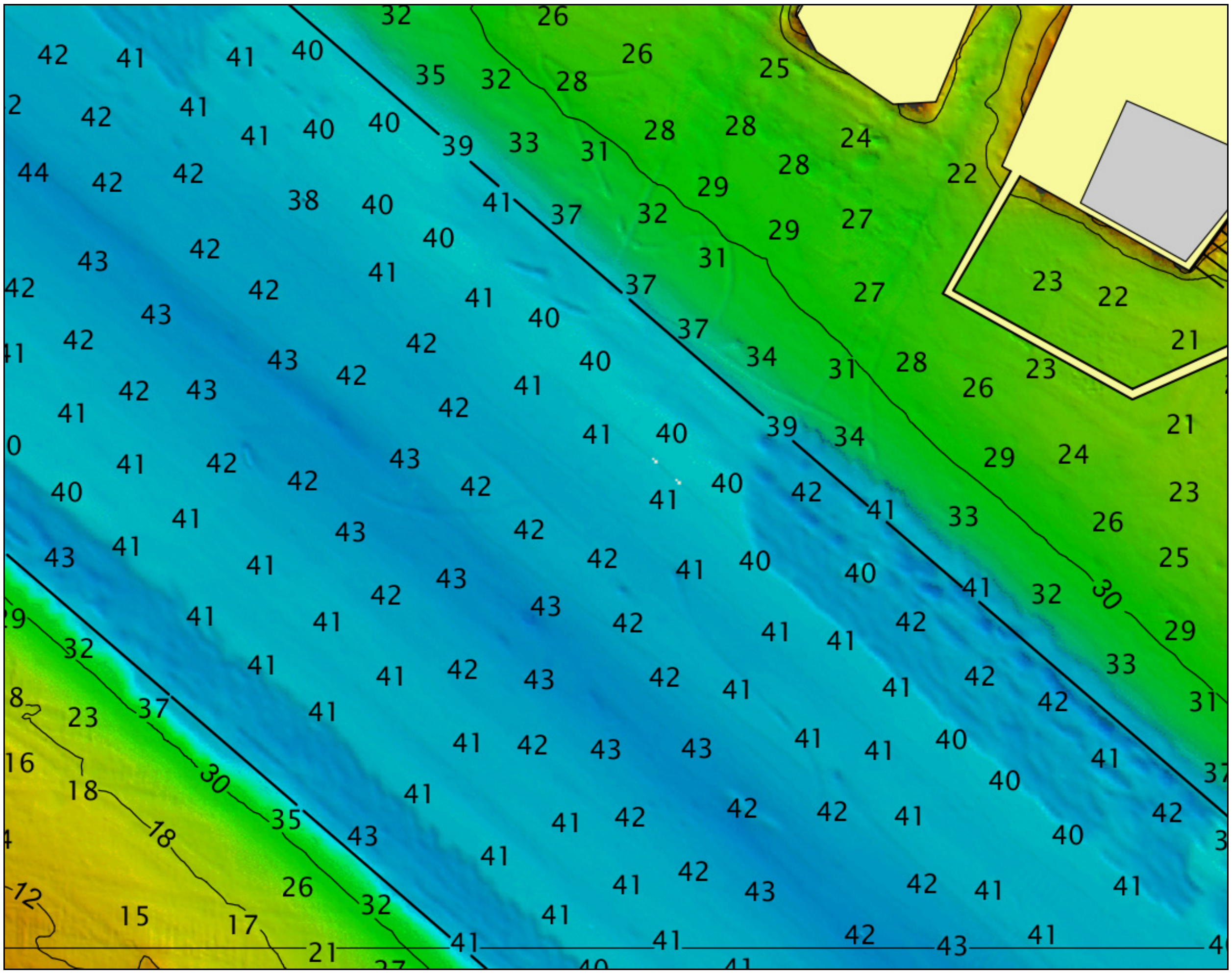

Figure 15: Close-up of Norfolk Inset 1:5,000 (units in feet), displayed with bathymetric surface

Finally, Figures 16 and 17 are replicates of Figures 10 and 11, presented this time with the bathymetric surface. The products are enhanced dramatically.

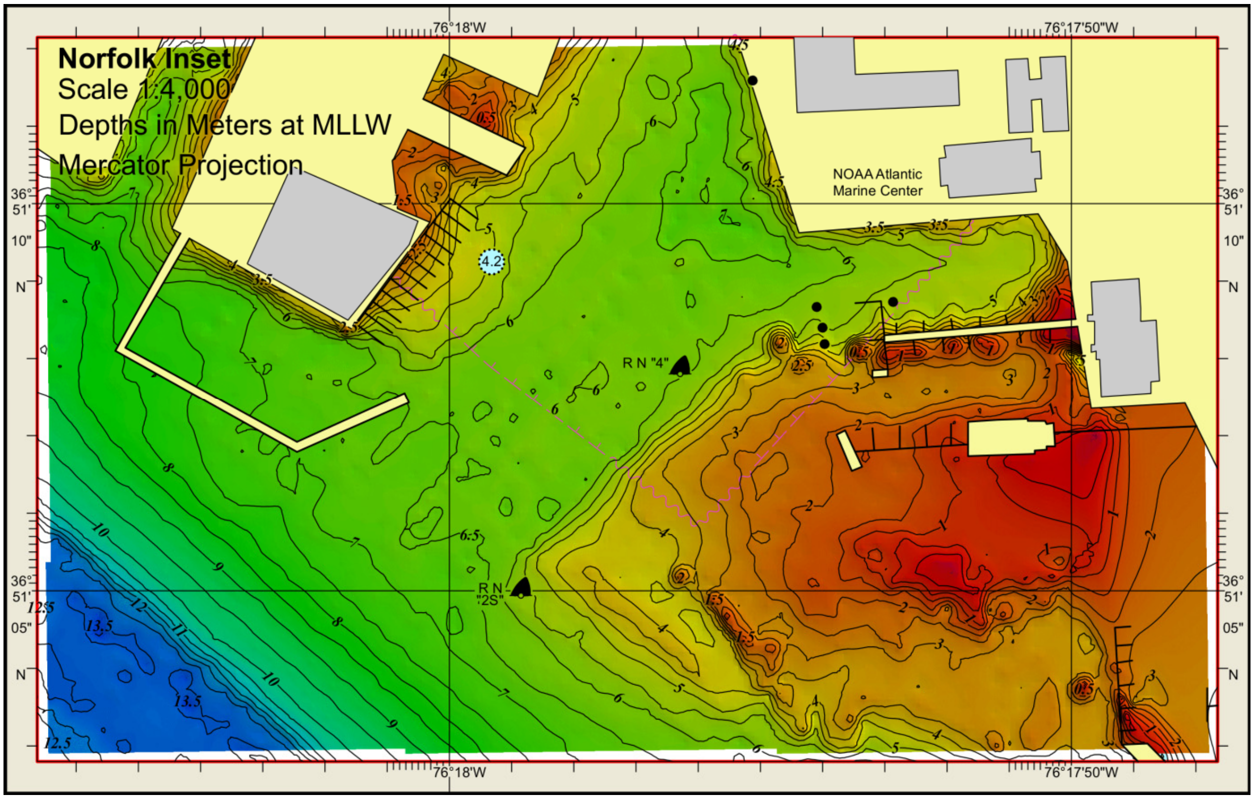

Figure 16: Norfolk Inset 1:4,000, displayed with bathymetric surface

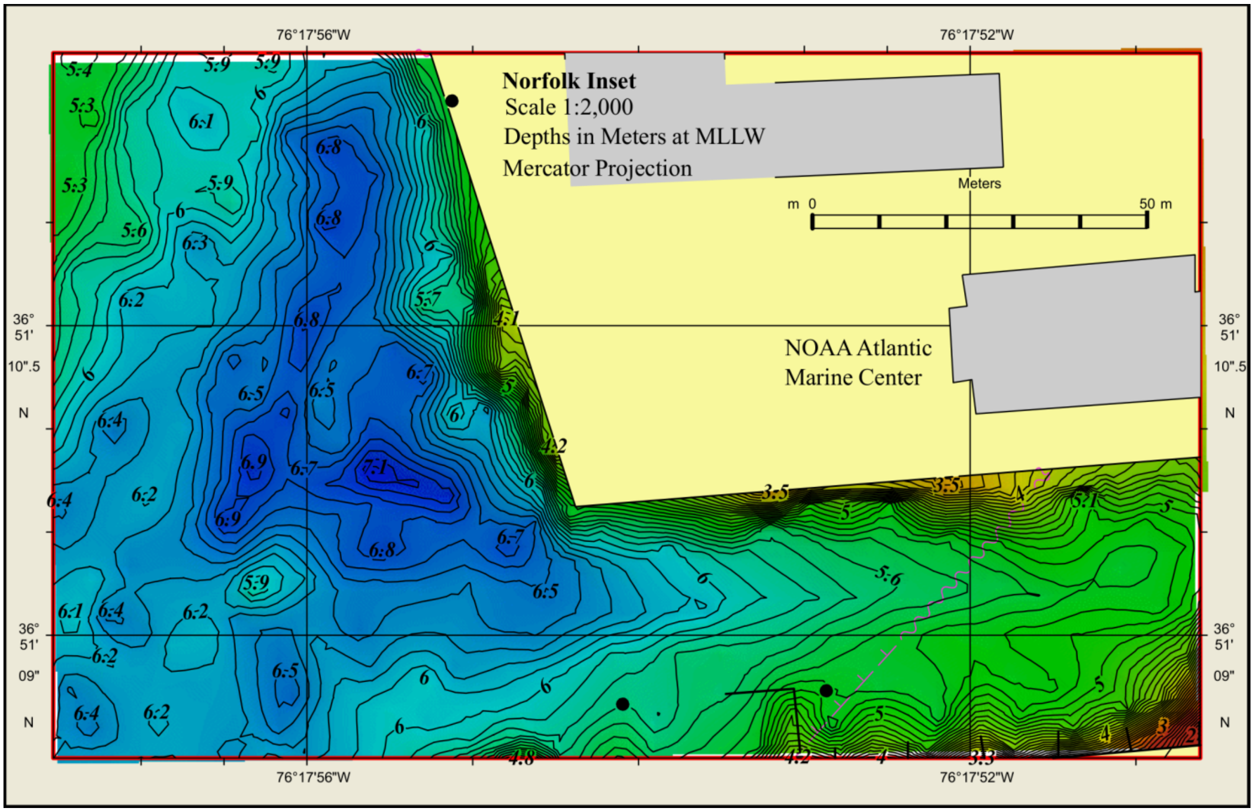

Figure 17: Norfolk Inset 1:2,000, displayed with bathymetric surface

It is obvious to see how the bathymetric surface significantly improves the resulting products. Potential chart products that incorporate the bathymetric surface directly will continue to be developed by the Port of Norfolk Project Team.

Implementation

As envisioned in the Port of Norfolk Project, the CARIS HPD suite of products, run on Oracle, could be used to maintain a seamless, high-resolution source database from which OCS could generate ENC and RNC products. The benefits and efficiencies gained are discussed widely throughout the various sections of this project. The work with CARIS HPD products is ongoing, with the end result being high-resolution ENC and RNC products of the Port of Norfolk in support of Operation Sail (OpSail) 2012 (part of which will occur in Norfolk). This event was targeted by the Port of Norfolk Project Team as a real-world application for the high-resolution products created during this endeavor.

Meanwhile, NOAA is several years into an effort to implement the Nautical Chart System II (NCSII), a system which utilizes ESRI's ArcGIS Production Line Tools (PLTS) Nautical Solution [Powell, 2009]. The system is similar to CARIS HPD in that it will source a seamless database in vector format called Nautical Information System (NIS). The goal is for this database to be the single source for all ENC and RNC production. Many of the efficiencies realized, and lessons learned, while experimenting with CARIS HPD, are translatable to the NSCII efforts.

NIS catalogs scale-dependent data into "scale bands", which are in theory the same as the usages in CARIS HPD. With these scale bands, the NIS source data could support the creation of the user-defined rasters as presented in this paper, so long as those scale bands at the largest scale preserve the kind of high-resolution bathymetric data observed in Figures 10 and 11. Within the scale bands, NIS could easily contain the necessary components for a high-resolution or multi-scaled ENC, however, NCSII would need the ability to contain the scale-dependent disposition of bathymetry and features, via algorithmic generalization, or scale-minimum/scale-maximum view displays, in order to support the actual creation of the advanced ENC product.

Conclusion

The concept of raster product generation, at user-defined bounds and scale, accessible online, would offer unmatched customer satisfaction, in that the user would get the exact product they want, for whatever their particular need may be. The raster products, if generated from the high-resolution source database as described by the Port of Norfolk Project, could offer bathymetric information well beyond the scope of what is currently available, in a form readily usable by the average customer of our online products webpage. Raster generation is mostly automated in HPD Paper Chart Editor—the primary challenge would be to automate the final presentation of the raster products, and to offer a selection of user-friendly output formats (GeoTIFF, BSB, GeoPDF). This goal is achievable, and would allow for easily accessible, user-defined raster product delivery. In addition, the direct utilization of a bathymetric surface in the creation of chart products from a source database would further enhance capabilities, allowing resulting products to be generated directly from the highest-level bathymetry, while eliminating the need for time-consuming generalization of bathymetric components.

Considering the efficiencies realized throughout the course of this project, and how much of the same concepts are prevalent with the implementation of NCSII, NOAA is clearly heading in the right direction with the institution of a seamless, single source, vector database, from which both ENC and RNC products will be derived. The resulting shift in production would allow for the generation of high-resolution products, as the ENC's would no longer be constrained by the scale of the RNC, and the resulting RNC's could be constructed to adequately meet the needs of any customer.

The implementation process of NCSII within NOAA is ongoing, and during this time the Port of Norfolk Project Team will continue efforts to develop capabilities within CARIS HPD, with the hopes to deliver high-resolution chart products of the Norfolk area in support of OpSail 2012.

Acknowledgements

The authors extend their sincere gratitude to the many who have helped make this project possible through their guidance, technical assistance, and constructive reviews, including but not limited to NOAA's Office of Coast Survey, the Marine Chart Division, the Hydrographic Surveys Division, the Operations Branch, the Remote Sensing Division, the officers and crew of the NOAA Ship *Thomas Jefferson*, Jeffrey Ferguson, CDR Richard T. Brennan, Gene Parker, Edward Owens, Sean Legeer, Kyle Ward, Vitad Pradith, Megan Greenaway, Mike Espey, and Nick Perugini. We also thank Karen Hart and Cameron McLeay of CARIS for the invaluable training and software support provided. Finally, we thank NOAA for its encouragement and support of research.

References

Caputo, R., 2010, The GeoPDF Project: Creating Maps for the Non-Mapper.

Casey, M., 2009, Citizen Mapping And Charting How Crowdsourcing is Helping to Revolutionize Mapping and Charting, *Proc. US Hydrographic Conference*, Norfolk, VA, USA, 11-14 May 2009.

Hodkinson, G., 2010, Introducing the Revolution in New Zealand Paper Chart Production, *Proc. FIG Congress*, Sydney, Australia, 11-16 Apr 2010.

Jones, K., 2010, Implementation of a Hydrographic Database Solution for Land Information New Zealand Hydrographic Services: Challenges and Efficiency Gains, *Proc. FIG Congress*, Sydney, Australia, 11-16 Apr 2010.

Miller, J.J., Mortimer, K., Self Miller, V., Wilson, M.J., and Wyllie, K., 2011, The Port of Norfolk Project: Feature Management in Support of High-Resolution Navigational Products, *Proc. US Hydrographic Conference*, Tampa, FL, USA, 25-28 Apr 2011.

Mortimer, K., Miller, J.J., Self Miller, V., Wilson, M.J., and Wyllie, K., 2011, The Port of Norfolk Project: Project Planning in Support of High-Resolution Navigational Products, *Proc. US Hydrographic Conference*, Tampa, FL, USA, 25-28 Apr 2011.

OpSail, Inc., 2011, webpage, http://www.opsail.org/extra/index.html.

Powell, J., Ence, C., Wallace, T., Jett, A., O'Dell, K., Lewis, M., Arias, J., Kearns, T., 2009, Using ArcGIS Nautical Solution to Produce Navigational Products, *Proc. US Hydrographic Conference*, Norfolk, VA, USA, 11-14 May 2009.

Self Miller, V., Miller, J.J., Mortimer, K., Wilson, M.J., and Wyllie, K., 2011, The Port of Norfolk Project: Assessing the Advantages of High-Resolution Navigation Products, *Proc. US Hydrographic Conference*, Tampa, FL, USA, 25-28 Apr 2011.

Wyllie, K., Miller, J.J., Mortimer, K., Self Miller, V., and Wilson, M.J., 2011, The Port of Norfolk Project: Processing Methodology for the Production of High-Resolution Navigational Products, *Proc. US Hydrographic Conference*, Tampa, FL, USA, 25-28 Apr 2011.