

Process for Capturing Real World Features from 3D Laser Scanned Point Clouds

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SUMMARY

The Hydrographic Survey Division at NOAA has been investigating the use of vessel-mounted LiDAR systems to compliment traditional surveying methods like multibeam and sidescan sonar to perform surveys along the coastline. The 3D scanned laser data has been found to augment and, in some cases, potentially replace traditional shoreline methods that can be time consuming, expensive, and dangerous. NOAA is developing new workflows for identifying and capturing features from the high density point clouds using CARIS Bathy DataBase (BDB).

This paper seeks to relay these first experiences using this kind of laser scanned data in a practical and time efficient way in the creation of features for charting and other purposes.

1. INTRODUCTION

1.1 Background

There are 95,471 miles of coastal shoreline in the United States that NOAA is responsible for portraying on its nautical charts (NOAA/PA 71046, 1975). One of the most challenging, time consuming, and dangerous tasks that NOAA hydrographic field units are presented with is verifying existing shoreline features, identifying and collecting data on new features, and then processing those shoreline features into a chart-ready product. Traditional methods for accomplishing these tasks involve deploying a small boat to perform discrete investigations of observed or assigned features of navigational significance using backpack mounted GPS equipment, handheld laser range finders, handheld compasses, digital point-and-shoot cameras, and data logging software. The vessel and crew are placed in a compromised position as they maneuver into shallow water and close to submerged features. The time increases substantially when the vessel is forced to stop and occupy a feature for a single point position.

A technology common to land surveying yet not as common in hydrographic surveying, laser scanning provides the potential for solving many problems that exist with the current shoreline verification process and technologies. By collecting accurate, high density, georeferenced LiDAR data from a moving vessel at a safe distance from features, laser scanner systems hold great promise in reducing the level of effort, time, and danger associated with the current process as well as providing a much more robust and valuable data set to NOAA's internal and external customers.



Figures 1a and 1b. Traditional Shoreline Verification and Vessel-Mounted LiDAR system

1.2 Data Collection

During the spring and summer of 2011 two NOAA hydrographic field units, NOAA Ship *Thomas Jefferson* and NOAA Ship *Fairweather*, experimented with vessel-mounted laser scanner systems to create 3D point clouds of the nearshore region in hopes of augmenting or replacing the current techniques used for shoreline feature verification.

Thomas Jefferson collected data in the Inner Harbor of Norfolk, VA in an area surrounded by cultural shoreline features such as piers, dolphins, and piles. *Fairweather* collected data near Kodiak, AK in an area surrounded by natural shoreline features such as rocks and islets. The two separate experiments were designed to evaluate the effectiveness of the 3D laser scan data in the two extreme environments of shoreline feature types that are seen by NOAA hydrographic field units. Both experiments utilized the Applanix™ LANDMark™ Marine mobile mapping system installed on one of their hydrographic survey launches. The laser scanners were attached to the launches using the included mounting platform. Data were acquired in two different ways on the two coasts: a single pass at 4 knots in Norfolk; and multiple passes of decreasing ranges at 8 knots during multibeam echosounder (MBES) data collection in Kodiak. Given the LANDMark™ system's ability to collect data at 10,000Hz and at a maximum range of 1700m, the launches were able to stay at a much safer distance from the shoreline features using the

LiDAR system than the traditional shoreline investigation methods require, while at the same time collecting a much more complete and accurate data set. The greatest benefit observed was that the laser acquisition did not take the field units additional time to collect yet there was an increase in personnel utilization efficiency and safety of operations while simultaneously providing a more robust data set than previously available.

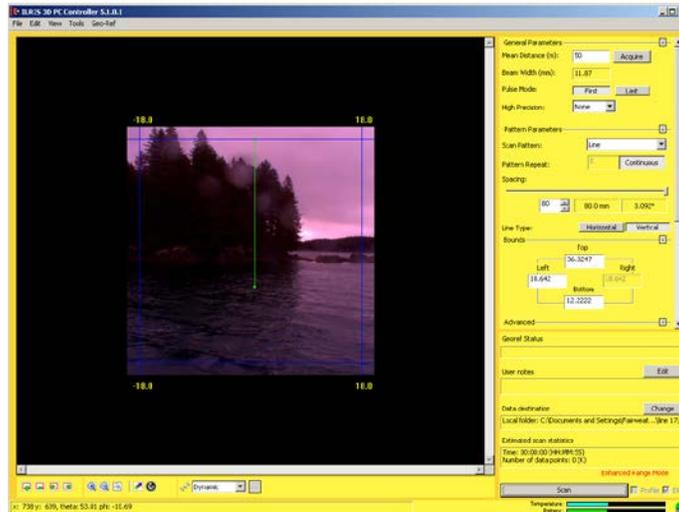


Figure 2. Screen Capture of LiDAR data acquisition in Alaska

1.3 Initial Processing

Each day the LANDMark™ system data were integrated with a Smoothed Best Estimate of Trajectory (SBET) to provide georeferencing and motion correction to the point cloud by using the supplied data processing tool. This Optech tool was configured to produce an ASCII file containing easting, northing, and elevation as well as 8-bit scaled intensity values. The ASCII files were then imported into BDB using a customized Information File, for processing and the creation of IHO S-57 attributed feature sets.

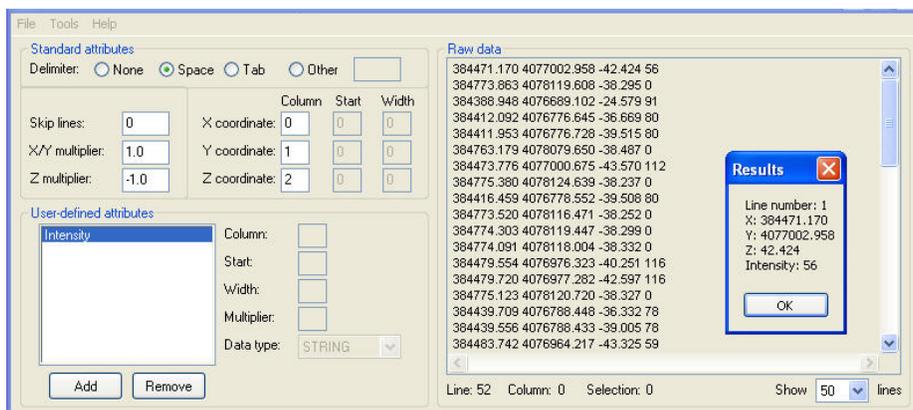


Figure 3. Creation of Custom BDB Information File

2. VIEWING POINT CLOUD DATA IN BDB

2.1. 3D View

After the data were imported into BDB using the customized Information File, they were able to be displayed in BDB's 3D View display. In the properties window, the color scheme was changed from the default color file of *Rainbow* to *Greyscale*. In order to fully utilize the intensity values that were imported with the easting, northing, and elevation data, the data were opened in 3D View and colored by the intensity of their return. While BDB has the ability to read and display real world RGB data if available with the laser acquisition data, the LANDMark™ system does not record RGB return data, therefore only x, y, z and intensity data were imported.



**Figure 4. Sample laser scan point cloud colored by RGB values in BDB 3D View
Data Credit: TerraDat UK / Topcon**

Intensity values ranged from 0-255. While the data contained minimal fliers, most of the erroneous data fell between the intensity values of 0-25. This was due mostly to sea surface reflection. The low intensity values can be filtered out before import or left in the data and analyzed during feature selection. Viewing the data colored by the intensity of the return provided more detail and a greater ability to decipher natural and cultural features in 3D View.

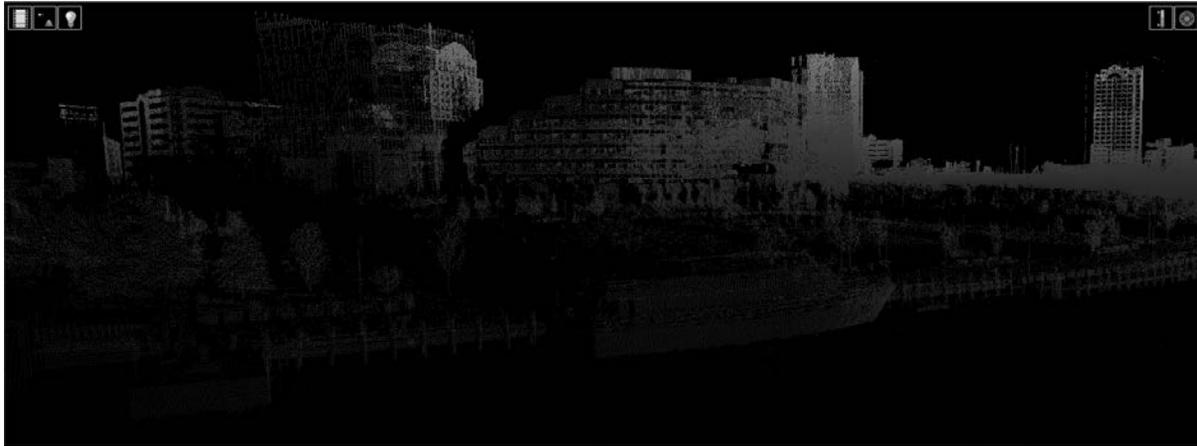


Figure 5a. Data viewed with color by Depth

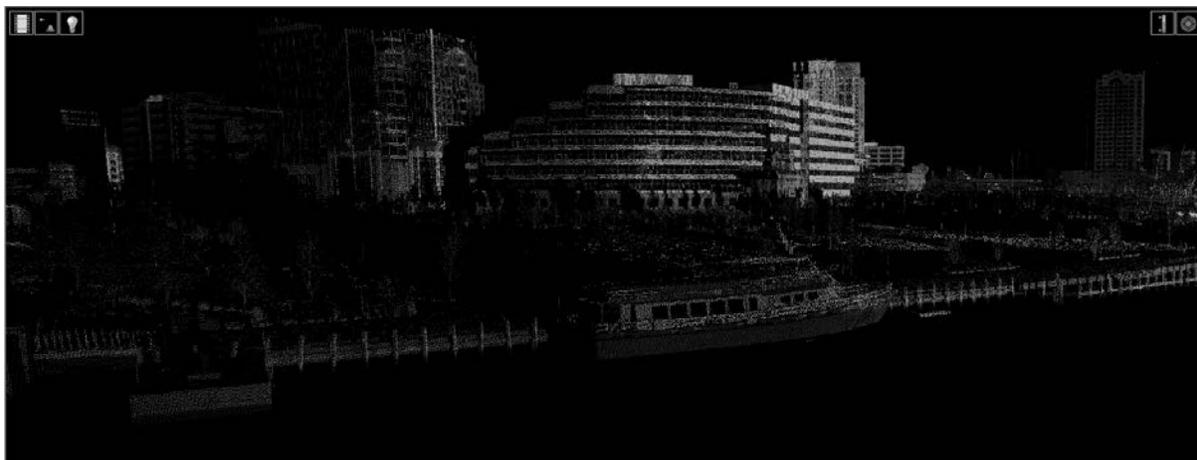


Figure 5b. Data viewed with color by Intensity

A selectable user preference available in BDB 3D View is the ability to change the point size to small, medium, large, or very large. This preference is useful when data is being presented on a screen other than a personal desktop so the point cloud data is more easily visualized. To assist with spatial awareness and correlation to the chart, both the 3D window and the 2D window were used simultaneously. The advantage of the dual view is that the 2D window has a yellow circle surrounding a black arrow that can be used as a navigation tool for the 3D View; wherever the yellow circle is dragged to in the 2D window, the 3D window will navigate to the same location.

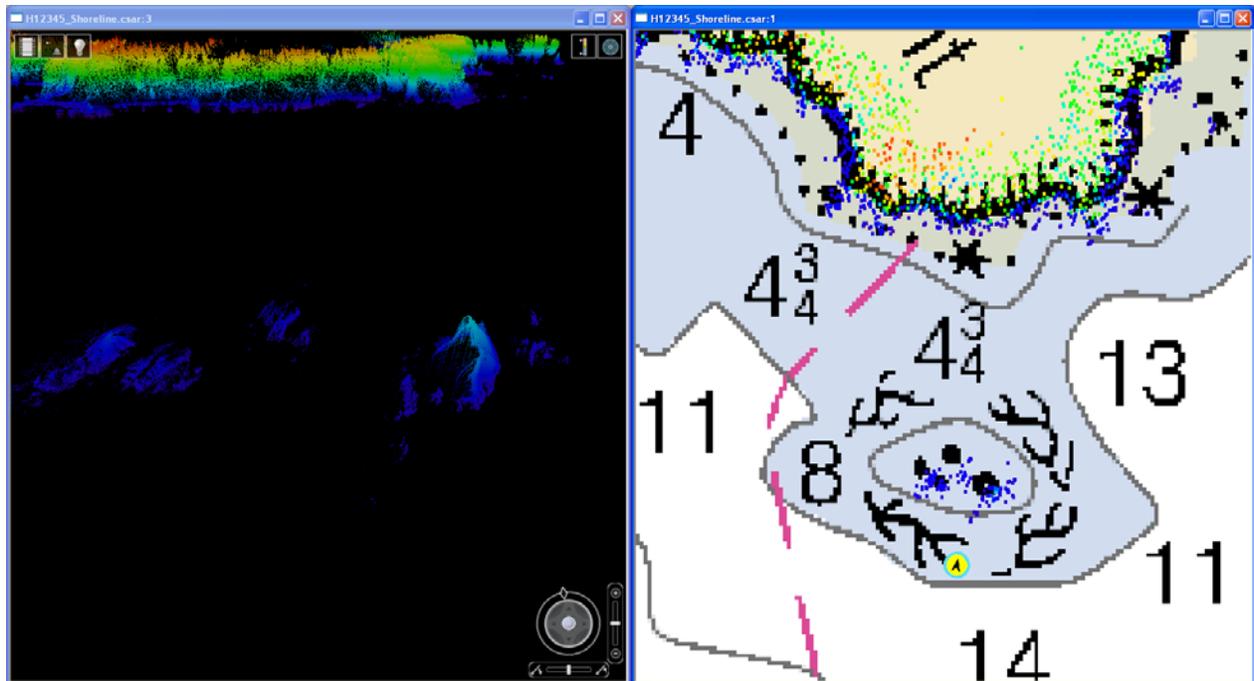


Figure 6. 3D and 2D windows tiled vertically

2.2 Subset Editor Mode

High density laser data can also be viewed and manipulated in BDB's Subset Editor. By selecting the parent layer of the point cloud data, the subset mode is made available. The processes and tools of BDB Subset Editor are the same as in CARIS HIPS. A subset box can be digitized over an area of interest and data can be viewed in 2D and 3D views. Subset view is the only tool currently in BDB to select 3D point cloud data to create a feature object. In future versions of HIPS and BDB, the subset editing tools will be fully integrated into the 3D view providing an enhanced experience for viewing, analyzing and selecting point cloud data.

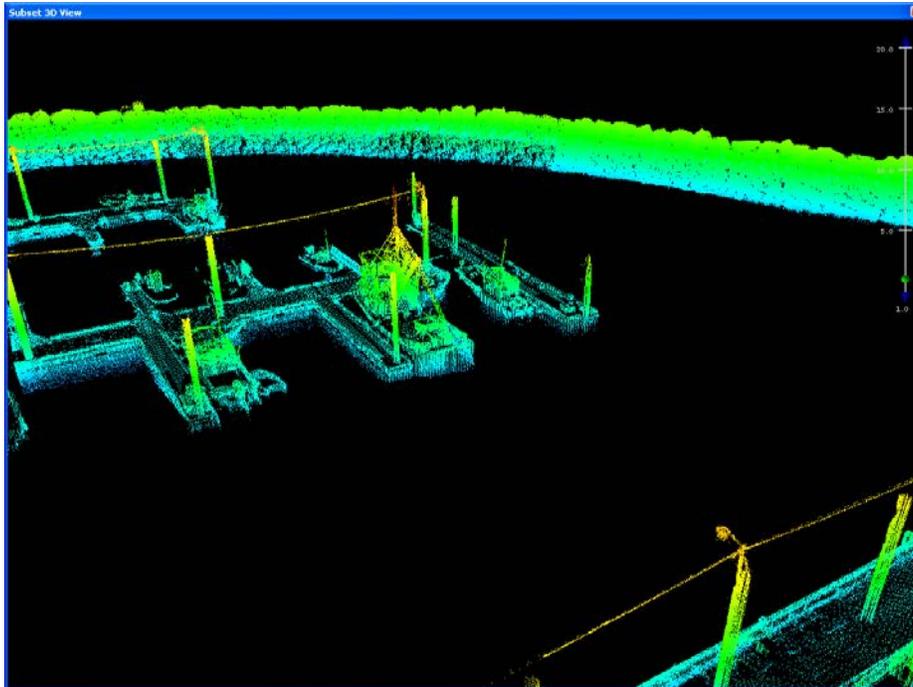


Figure 7. BDB Subset Editor 3D View

3. CREATING FEATURES FROM POINT CLOUD DATA

3.1 Vertical Shift

The laser data imported into BDB were referenced to the GRS 80 ellipsoid. In order to analyze the data in the context of the chart, the data had to be shifted to the Mean Lower Low Water chart datum. This was accomplished in BDB with the Vertical Shift Surface tool. The point cloud data were shifted by an ASCII separation model file. The *Fairweather* used a separation model file solution generated by the Ellipsoidally Referenced Zoned Tides (ERZT) method (Rice and Riley, 2011). The *Thomas Jefferson* used a separation model file solution generated from NOAA's National Ocean Service VDatum (<http://vdatum.noaa.gov/>).

3.2 Point features

Point features were designated from the high density point cloud data in 3D Subset View. The process for designating data points was analogous to designating least depths on submerged features in HIPS. A subset box was created over the center of a feature and the data points were selected, queried, and sorted by elevation. The highest elevation was evaluated for an intensity value and designated as appropriate. After exiting the 3D Subset View, a new child layer containing the designated soundings appeared under the parent layer of the point cloud data. The designated sounding(s) were then selected and imported into a new feature layer with the appropriate S-57 feature object class and attribution.

A similar but alternate workflow to designating soundings for feature selection would be to query the data points from the mapview, select the highest elevation, and directly import that data point into a new feature layer.

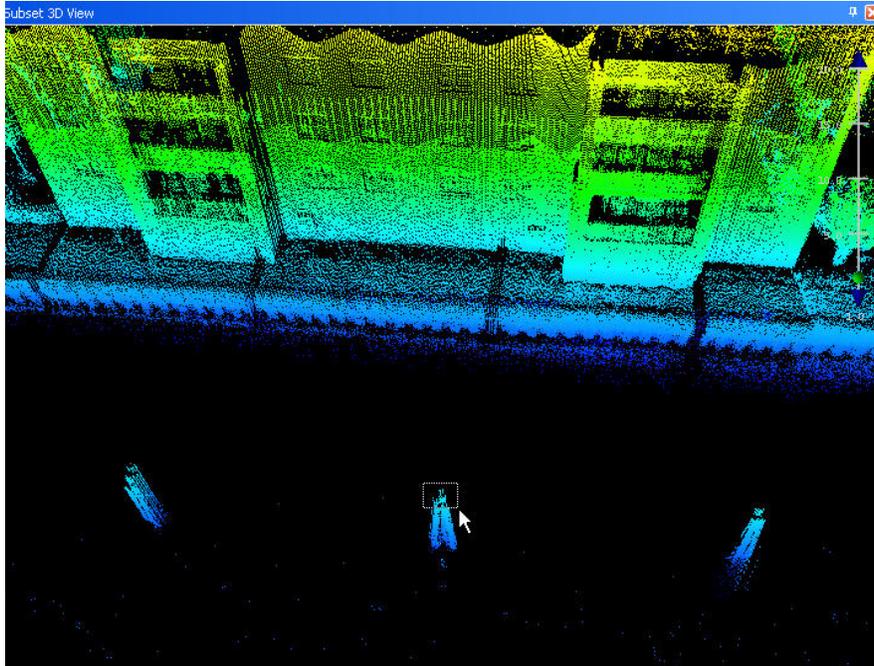


Figure 8a. Subset 3D View

	Latitude	Longitude	Z (ft) ▲	Status	Intensity
1	36-50-56.6...	076-17-42....	-6.987	Designated	186.0
2	36-50-56.6...	076-17-42....	-6.941	Accepted	245.0
3	36-50-56.6...	076-17-42....	-6.892	Accepted	0.0
4	36-50-56.6...	076-17-42....	-6.780	Accepted	78.0
5	36-50-56.6...	076-17-42....	-6.770	Accepted	215.0
6	36-50-56.6...	076-17-42....	-6.767	Accepted	39.0
7	36-50-56.6...	076-17-42....	-6.767	Accepted	245.0
8	36-50-56.6...	076-17-42....	-6.711	Accepted	117.0
9	36-50-56.6...	076-17-42....	-6.613	Accepted	88.0
10	36-50-56.6...	076-17-42....	-6.587	Accepted	206.0
11	36-50-56.6...	076-17-42....	-6.580	Accepted	88.0
12	36-50-56.6...	076-17-42....	-6.570	Accepted	107.0
13	36-50-56.6...	076-17-42....	-6.547	Accepted	206.0
14	36-50-56.6...	076-17-42....	-6.468	Accepted	68.0
15	36-50-56.6...	076-17-42....	-6.459	Accepted	68.0
16	36-50-56.6...	076-17-42....	-6.409	Accepted	117.0
17	36-50-56.6...	076-17-42....	-6.396	Accepted	235.0
18	36-50-56.6...	076-17-42....	-6.327	Accepted	215.0

Figure 8b. Querried laser data of dolphin

3.3 Line and Area Features

Surveyed features that had geometry of a line or area (i.e. piers) followed the same logic as point feature designation, but with an additional step. The line or area feature was observed in subset 3D view and data points were designated for the seaward extent of the feature, illustrating the width and length of the feature.

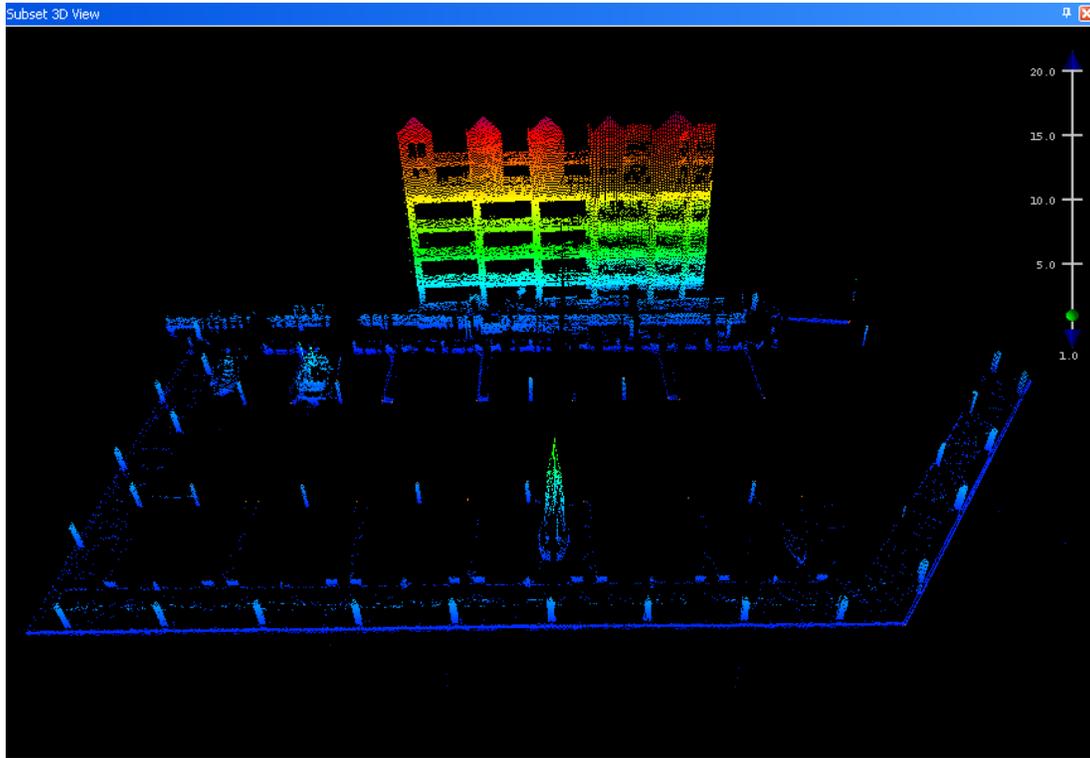


Figure 9. Designating extent of pier

After exiting Subset View, the designated soundings were selected and imported into a new temporary feature layer as cartographic symbol (\$CSYMB) feature objects. When digitizing the line or area feature, the temporary cartographic symbol layer was used as the snap layer to retain laser geometry during digitization.

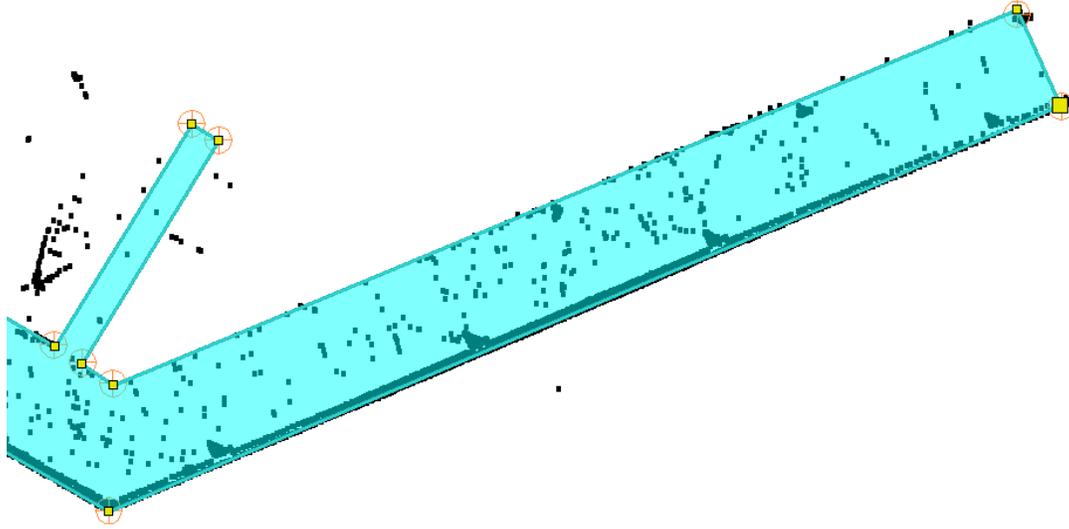
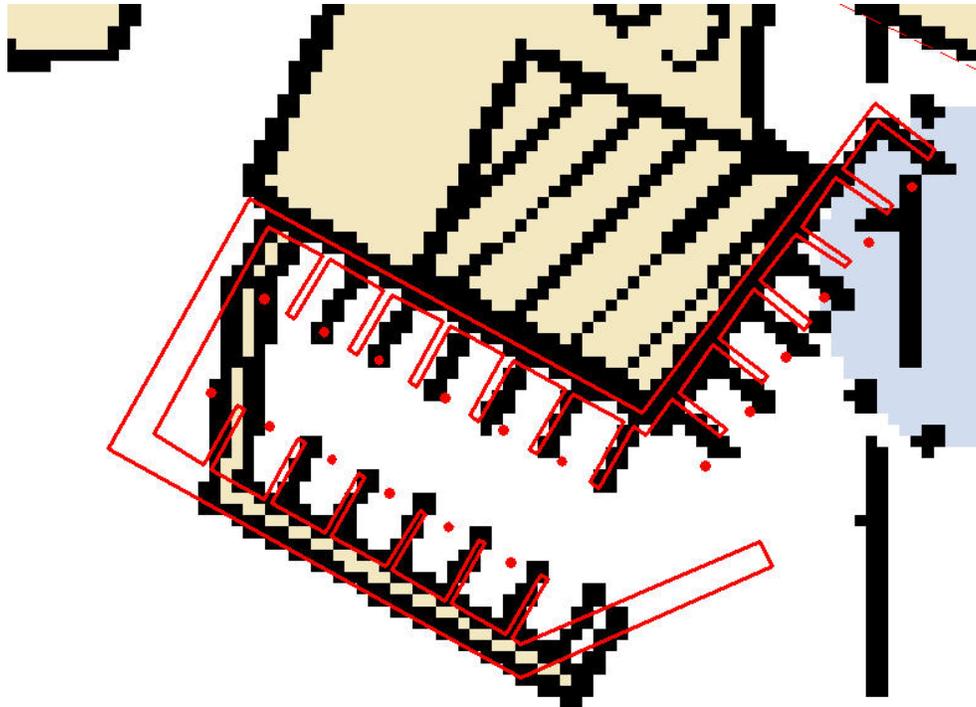


Figure 10. Digitizing an area feature from laser data



**Figure 11. Example of pier digitized from laser data.
Note that graphic is over-zoomed beyond chart scale**

3.4 Attribution

All features were required to be fully S-57 attributed as well as attributed with additional NOAA extended attributes. To minimize the time spent on attributing features individually, BDB's Change All tool was used for mass-edits of feature classes as well as attribute values. This Change All tool was mostly used on features of the same feature class as mandatory attribution can change between feature classes.

4. RESULTS

4.1 Features

The laser data density is considered to be a scale-less source from which chart-scale features can be created or generalized. The most challenging aspect of this process is determining which feature identified in the laser scanner data can be represented at scale, or how a group of features should be generalized.

For the *Thomas Jefferson* survey, the goal of the survey was to collect data "shoreline to shoreline" at a scale twice that of the existing raster chart for the purpose of creating a chart inset. There were 517 features resulting from laser data, of which 308 were uncharted. The remainders were currently charted features that either were updated with a new position or height, or retained as charted. The majority of those features were cultural features like dolphins, piles, and piers.

The *Fairweather* was provided a Composite Source File that included 322 features of which only 23 were assigned for normal shoreline investigation (Ward and Palmer, 2008). The majority of features were natural shoreline features like rocks and islets. While there were concerns about how the system would perform in regards to rocks awash, rocks with kelp cover, and features covered by foliage; the system performed well each scenario. The laser scanner captured data on the entire 322 features in a lesser amount of time than the 23 features were investigated with traditional means. The laser was able to acquire more statistically valid heights with the spatial extents fully expressed in the point cloud.

A common workflow was developed for both *Thomas Jefferson* and *Fairweather* laser data processing using BDB. NOAA has partnered with CARIS to implement changes to their BDB software that will support this workflow and provide tools that will more easily support the creation of cartographic features at a product scale from laser scanner data. In particular, the ability to digitize features in BDB's 3D View would further reduce the workflow and expedite feature creation. Viewing geo-tagged photos in a thumbnail form at their geographic position in BDB's mapview window as well as in the S-57 'PICREP' field or NOAA's extended attribute field of 'images' would also be a benefit when real world RGB data is unavailable with data acquisition.

4.2 Quality Control

While the LANDMark™ system contains an internal camera, it does not record pictures that can be used during post processing. To aid in resolving ambiguity in the point cloud data during post processing, a digital still camera with geo-tagging capabilities was utilized while collecting the laser data. The photos were geo-tagged using the EXIF v2.3 standard during creation and then displayed in their geographic position in Google™ Earth Pro. The point, line and area features digitized from the laser data were also exported to .kml format and displayed in Google™ Earth Pro. If multibeam or sidescan data were available, that data was also referenced when any ambiguity arose. Future work could benefit from a camera capable of acquiring geo-tagged 360 degree video in order to eliminate ambiguity in the point cloud.

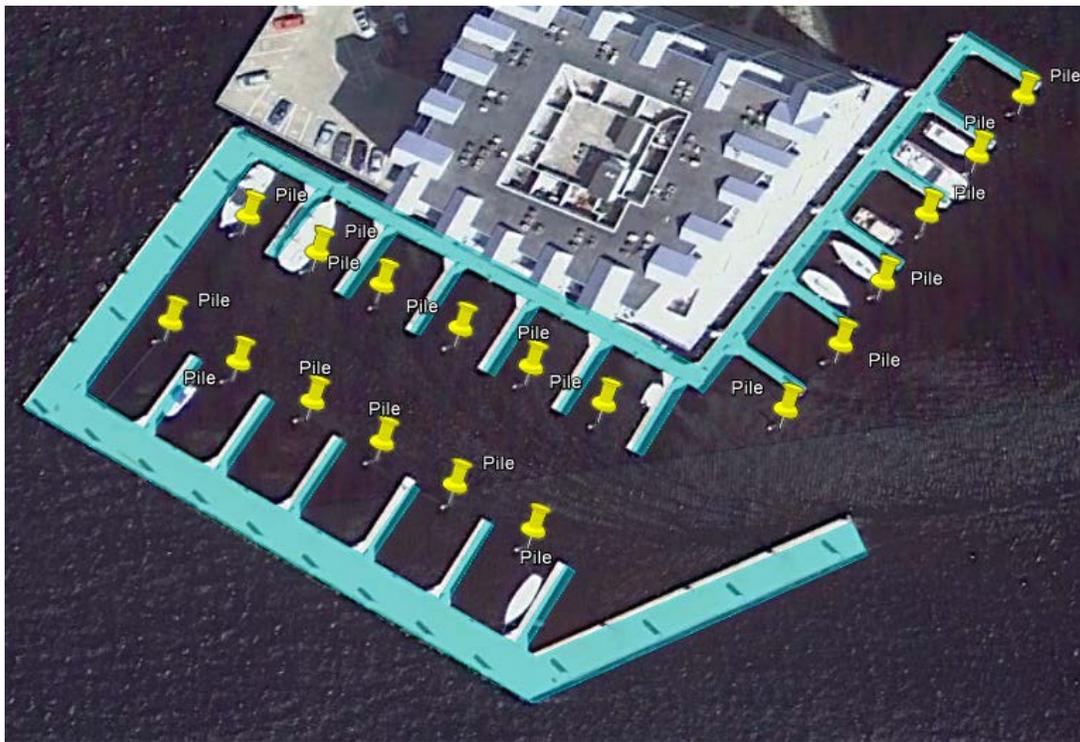


Figure 12. Features sourced from laser data displayed in Google™ Earth Pro

5. LOOKING AHEAD

With any new technology implemented during field acquisition, ample testing of the hardware and software is required in order to assess the resulting efficiencies. The data collected by *Fairweather* and *Thomas Jefferson* were used to develop a point cloud-to-feature workflow. More data are needed to make meaningful comparisons to current shoreline data acquisition in terms of time, money, and safety. Working with additional systems and data sets will aid in further refinement of software processing tools.

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BIOGRAPHICAL NOTES

Katrina Wyllie is a Physical Scientist with NOAA's Atlantic Hydrographic Branch in Norfolk, VA. She earned her BS in Marine Biology at College of Charleston (2008). Her current tasks at NOAA include completing quality assessment reviews of hydrographic surveys, generating chart update products, and assisting on hydrographic vessels.

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